JOURNAL OF DAIRY SCIENCE

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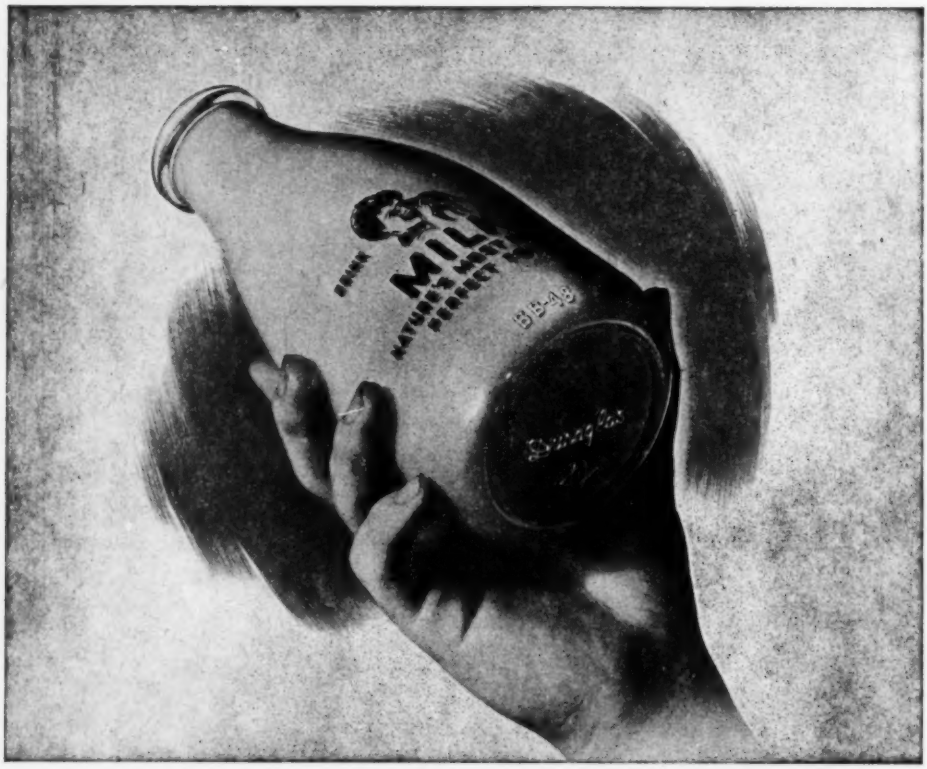

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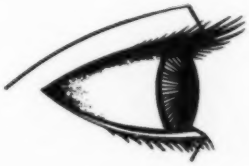

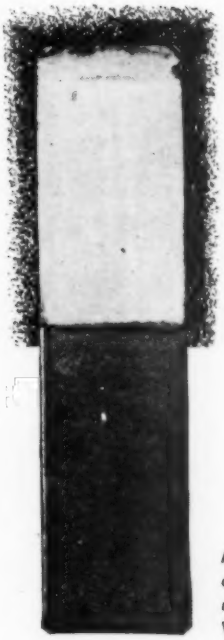

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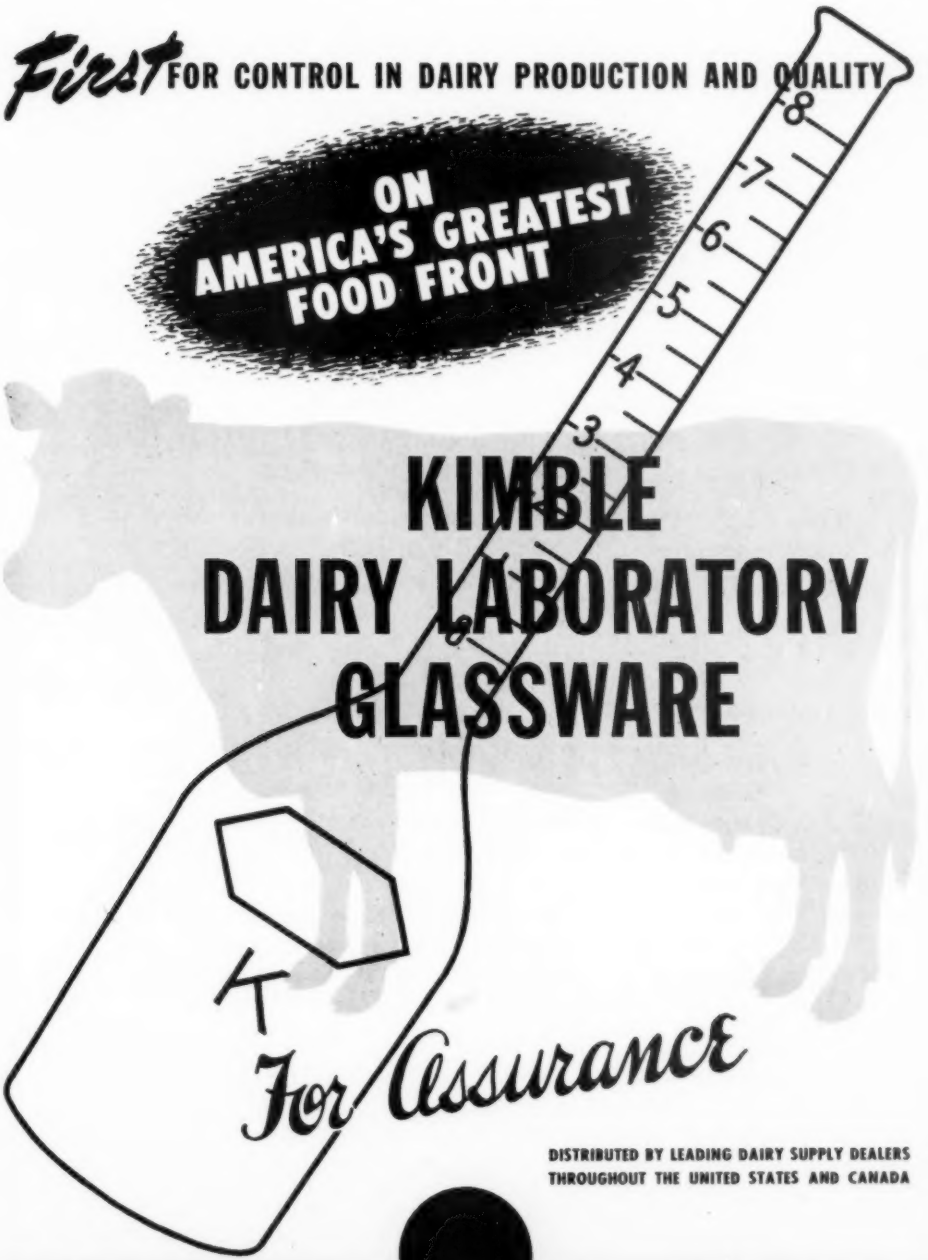
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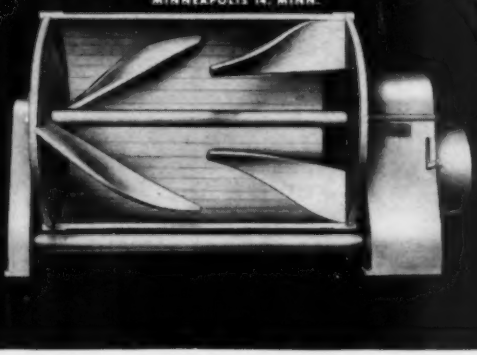

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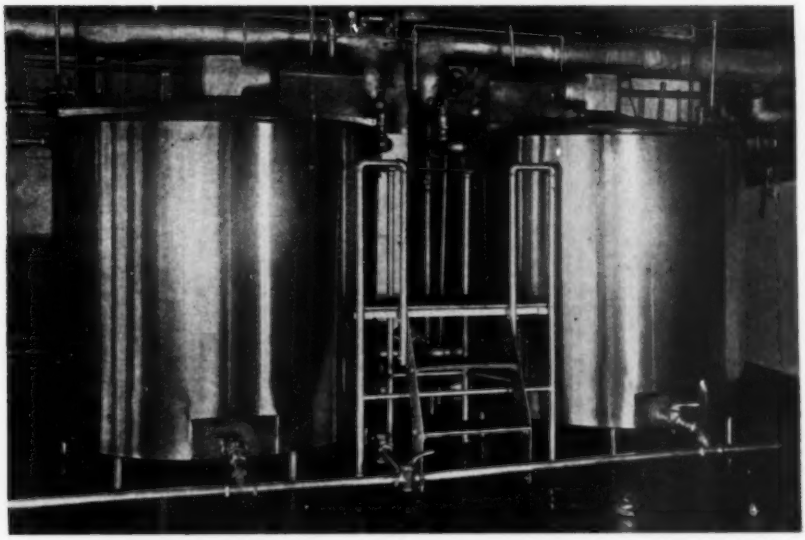

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JOURNAL OF DAIRY SCIENCE

VOLUME XXVII NOVEMBER, 1944 NUMBER 11

THE DETERMINATION OF TANNIC SUBSTANCES IN COMMERCIAL COCOA POWDERS

W. S. MUELLER AND J. W. KUZMESKI[1]

Massachusetts State College, Amherst, Massachusetts

INTRODUCTION

Cocoa and chocolate are extensively used in connection with milk and some of its products, viz., chocolate milk, chocolate ice cream, chocolate puddings, and milk chocolate candies. Recent data (7) indicated a close connection between the content of tannic substances in cocoa powder, as determined by the Ulrich method (8), and its toxicity when cocoa was fed with whole milk powder to white rats. Thus, the tannic substances appear to be of sufficient importance to warrant further investigation of their presence in commercial cocoa powders.

Although the tannic substances of cocoa have not been defined too clearly in the literature, it may be assumed that they may include cacao-tannin, cacao-purple[2] and cacao-brown (1, 5). The amount of these various tannic substances present in commercial cocoa powder depends to a great extent upon treatments, such as fermentation, drying, roasting, and addition of alkali (Dutch process), and to a lesser extent upon the variety of the cocoa bean used.

Various methods have been worked out for the determination of the tannic acid content of plant materials, yet they do not seem appropriate for cocoa products. The writers are not aware of any published methods which will determine accurately the tannic substances totally or separately in cocoa powder. Several methods have been suggested for the determination of cacao-purple. Heiduschka and Bienert (4) do not claim that their method is accurate enough for analytical work. Ulrich's (8) method for the determination of cacao-purple, which is a constituent of the cacao nib but thought to be absent in the shell, was proposed chiefly as a method for detecting

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[1] Department of Dairy Industry and Control Service cooperating. Contribution No. 514 of the Massachusetts Agricultural Experiment Station.

[2] In this paper cacao-purple is considered as being synonymous with cacao-red. Fincke (2) christened this tannic substance cacao-red, but Knapp (5) considers cacao-purple preferable as this more accurate color description assists in distinguishing it from the oxidation products which are of red-brown color.

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cocoa shell in commercial powders. The Ulrich method became the generally accepted test for cacao-purple of cocoa powder. However, Fincke (3) reported this method unreliable for this purpose.

Since the accuracy of Ulrich's method has been questioned, an attempt was made in this study to improve the method. The results obtained are given as a report of progress. Fifteen samples of commercial cocoa powder were analyzed by Ulrich's method before the writers were aware that the accuracy of this method had been seriously questioned. The results are included here, so that they may be compared with analyses of cocoa samples of less recent date, reported by other investigators.

EXPERIMENTAL

Analyses of cocoa powders by Ulrich's method. Fifteen samples of commercial cocoa powder were analyzed by Ulrich's method. In this method the material to be investigated is boiled with 50 per cent acetic acid, the filtrate is mixed with hydrochloric acid and precipitated by means of ferric chloride, and the precipitate is washed with hot water, filtered off, and weighed. The results of the analyses are summarized in table 1 as average percentages

TABLE 1

Average values for ferric chloride precipitates of cocoa powders

	Original samples	Moisture-fat-free basis
	per cent	*per cent*
6 Dutch and 9 unprocessed	11.01	14.13
6 Dutch samples	8.44	10.74
9 Unprocessed samples	12.72	16.42
4 Dutch samples when Dutch and unprocessed samples were made from similar base beans	8.68	11.27
4 Unprocessed samples when Dutch and unprocessed samples were made from similar base beans	12.86	17.06

of ferric chloride precipitate calculated on moisture-fat-free basis and on the original sample.

The average value of 14.13 per cent of ferric chloride precipitate, calculated on a moisture-fat-free basis, approximates the figures reported by other investigators, namely 13.81 per cent by Ulrich (8) and 15.17 per cent by Lythgoe (6). However, the figure for Dutch cocoa is lower than that reported by Lythgoe. Among the Dutch and unprocessed cocoa samples analyzed, four samples of each were made from the same type of cocoa beans and such samples should give a more accurate comparison than samples of unknown history. Obviously, it would be desirable to have samples of Dutch and unprocessed cocoa which were made from the same lot of beans, but sufficient samples of this type were unavailable. The average percentage of ferric chloride precipitate was approximately one-third less for the

Dutch cocoa than for the unprocessed cocoa. Moisture and fat in the cocoa samples ranged from 1.09 to 5.32 per cent and 10.10 to 23.71 per cent respectively.

Modification of Ulrich's method. Since Ulrich does not indicate the basis of his method or the nature of the material brought to precipitation, the precipitated material is usually referred to simply as "ferric chloride precipitate." Some investigators, however, have reported the amount of ferric chloride precipitate as if it consisted entirely of tannic substances.

Numerous ferric chloride precipitates were analyzed in this study in an attempt to secure some information on the nature of the material precipitated; also, the effect of altering the procedure for washing the precipitate was studied. The results are given in table 2. The ferric chloride precipitates, washed according to Ulrich's method and ashed, had an average ash content of 13.45 per cent, which varied from 11.48 to 18.24 per cent. Analyses of the ash showed it to consist mainly of iron and phosphorus, present either as separate oxides or in combination as ferric phosphate. The relatively high ash content of the ferric chloride precipitate indicated that the weight of the precipitate cannot be taken as a true measure of cacao-purple or other tannic substances, because the value is too high, at least to the extent of the weight of ash in the precipitate.

In order to determine whether the ash content could be reduced, thereby making the weight of the ferric chloride precipitate more nearly a true measure of the amount of tannic substances present in cocoa powder, it was decided to alter the portion of the Ulrich procedure which pertained to the washing of the precipitate. Qualitative tests made on a number of precipitates, which had been washed with hot water according to the Ulrich method, showed the presence of small amounts of chloride, indicating that some of the iron appearing in the ash probably was due to incomplete removal of ferric chloride by washing. Two modifications in washing the precipitate were used. Some precipitates were washed first in cold acetic acid (1+1) and then in hot water. Other precipitates were washed with a cold mixture of acetic and hydrochloric acids of the same concentration as used in extracting the tannic substances, the final washing likewise being with hot water. In general, washing the precipitate with either acid solution resulted in a lower percentage of ash in the precipitate and a lower percentage of iron and a higher percentage of phosphorus in the ash. However, the mixture of acetic acid with hydrochloric acid was more effective than the acetic acid alone. Whatman No. 42 filter paper and a filter crucible were also compared as to their desirability for use in collecting and washing the precipitate. The washing was slightly more effective when the filter crucible was used, but the difference appeared too small to be of any great significance. It was also noted that the proportion of iron to phosphorus approached the theoretical proportions existing in ferric phosphate, when the precipitates were washed with acid.

TABLE 2

Analyses of ferric chloride precipitate

Sample No.	Brand No. and kind of cocoa	Treatment of precipitate	Per cent $FeCl_3$ ppt.		Per cent ash in ppt.	Per cent Fe in ash	Per cent P in ash	Per cent Fe and per cent P in ash calculated to per cent $FePo_4$	Excess Fe in ash calculated to per cent Fe_2O_3	Excess P in ash calculated to per cent P_2O_5
			On dry fat-free basis	On original sample						
1	II Dutch	According to Ulrich's method*	15.91	11.95	11.96	40.6	.....	.....	.....	.....
2	II Unprocessed	" " " "	17.77	13.08	11.48	39.2	.....	.....	.....	.....
3	III Dutch	" " " "	17.17	13.84	11.95	42.3	15.6	75.9	20.3	.....
4	III Unprocessed	" " " "	16.29	11.57	12.76	41.4	17.1	83.1	15.2	.....
5	IV Dutch	" " " "	7.42	5.43	18.24	44.8	14.6	71.0	26.4	.....
6	IV Unprocessed	" " " "	16.50	13.35	12.78	45.2	15.0	72.9	26.0	.....
7	XII Dutch Liquor	" " " "	10.28	4.55	17.48	42.2	13.4	65.2	25.9	.....
8	XII Unprocessed Liquor	" " " "	16.02	6.95	14.51	40.8	14.6	71.0	20.7	.....
9	XI Unprocessed	" " " "	16.53	13.54	11.55	45.6	15.1	73.4	26.3	.....
9a	"	Used Whatman No. 42 filter paper washed ppt. with cold 50–50 acetic acid. Finished washing with hot water	15.71	13.06	9.80	39.3	18.6	90.4	8.3	.....
9b	"	Used filter crucible. Washed ppt. same manner as for 9a	16.55	13.80	9.50	38.3	18.1	88.0	8.1	.....
10	X Unprocessed	According to Ulrich's method*	13.78	10.91	11.80	45.4	15.3	74.4	25.6	.....
10a	"	Used Whatman No. 42 filter paper washed ppt. with cold acetic acid + HCl acid. Concentration of acid mixture same as precipitating solution. Finished washing with hot water	13.53	10.50	7.51	33.3	22.8	90.0	.....	9.8
10b	"	Used filter crucible. Wash ppt. in manner as for 10a	13.57	10.67	7.13	31.6	23.1	85.4	.....	12.6

* Used Whatman No. 42 filter paper and washed ppt. with hot water until filtrate gave negative test for Fe with $K_4Fe(CN)_6$.

SUMMARY AND CONCLUSIONS

1. Fifteen samples of commercial cocoa powders were analyzed, presumably for cacao-purple, by Ulrich's ferric chloride precipitate method. The ferric chloride precipitates ranged from 3.48 to 15.59 per cent, with an average of 11 per cent. The average percentage of ferric chloride precipitate obtained from Dutch cocoas was approximately one-third of the amount obtained from the unprocessed cocoas.

2. The amount of ferric chloride precipitate does not measure accurately the amount of cacao-purple or other tannic substances in cocoa, partly because the ash content of the precipitate was found to be relatively high, averaging 13.45 per cent.

3. The ash consisted mainly of iron and phosporus, present either as separate oxides or in combination as ferric phosphate.

4. A modification of the method of washing the ferric chloride precipitate has been suggested, which reduced its ash content.

5. Results obtained from this study indicate that the ferric chloride precipitate would measure the tannic substances content of cocoa more accurately if the modification of the washing procedure were followed and correction made for the ash contained.

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THE RECOGNITION OF THE INFLUENCE OF AGE ON BUTTERFAT PERCENTAGE WHEN CALCULATING MATURE EQUIVALENTS*

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INTRODUCTION

The use of conversion factors in calculating dairy cattle production records to standard equivalents has become an accepted procedure. General recognition has been given to the fact that as dairy cows increase in age their milk and butterfat production increases until senescence brings about a gradual decline from year to year. It has also been shown (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17) that fat percentage travels a related but inverse line. Fohrman (4) and Heizer (13) have also shown that the milk and butterfat production for dairy cows increases at a dissimilar rate which justifies different age conversion factors for milk and butterfat. The results of these studies, however, have been given no consideration by the various agencies that report production records on a standardized equivalent basis. The present procedure is to multiply the actual milk production by a factor, and then multiply the actual butterfat production by the same factor. It is the purpose of this paper to offer additional proof of the effect of age on the butterfat percentage in the milk of dairy cows, and to point out the error resulting from the use of the present method of calculating mature equivalents for milk and butterfat production.

PRESENTATION OF DATA

In 1941 the Ayrshire Breeders' Association placed all of its production records on punch cards and approved the use of these cards for analytical purposes by the Department of Dairy Husbandry of the West Virginia Agricultural Experiment Station. The first 34,176 of these records are involved in this study. These records were for complete lactations not exceeding 305 days in length. They were sorted on the basis of the age of the cow at the beginning of the lactation.

The effect of age on the butterfat percentage in the milk of Ayrshire cows is shown in table 1. This table contains the number of animals in each age group, the actual butterfat percentages for the different ages, and conversion factors calculated from these various percentages.

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TABLE 1

Butterfat tests of Ayrshire cows at different ages and corresponding age conversion factors

Age of cow beginning of record (years)	Number of records for each age group	Average butterfat percentage	Butterfat percentage differentials	Age conversion factors for per cent butterfat
2	8,238	4.09	−0.10	0.9755
3	6,794	4.07	−0.08	0.9803
4	5,305	4.05	−0.06	0.9852
5	4,037	4.02	−0.03	0.9925
6	3,123	3.99	.....	1.0000
7	2,302	3.96	+0.03	1.0007
8	1,637	3.94	+0.05	1.0130
9	1,185	3.91	+0.08	1.0200
10	762	3.90	+0.09	1.0230
11 & over	1,114	3.87	+0.12	1.0310

The accompanying figure shows the regression of butterfat percentage on age of cow at the beginning of the record.

DISCUSSION

The variation in the per cent butterfat in the milk of Ayrshire cows at different ages, as shown in table 1, suggests the necessity of a change from the present method of calculating mature equivalent production records. Practically all conversion factors in use were worked out for total butterfat, rather than for milk. It has become the general practice, however, to apply these butterfat conversion factors to both milk and butterfat. By this method an error is introduced which, although considered insignificant by some investigators (6, 14, 15, 17), is, according to the data involved in this study, statistically significant and is of importance economically both in a breeding program and in a dairy enterprise.

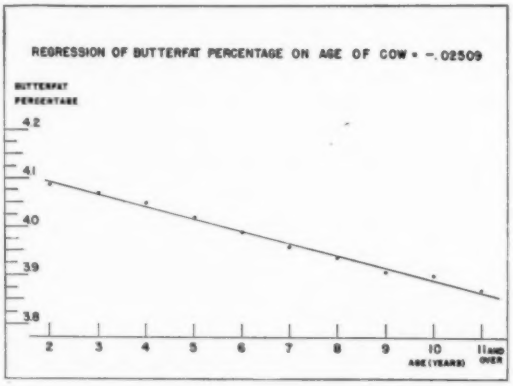

FIG. 1

Conversion factors are a necessary evil to which we must resort in making mature equivalent production comparisons of dams and daughters in evaluating sires. It is a recognized fact that when applied to individual records conversion factors may err greatly as an indicator of mature performance. Deliberate applications of conversion factors to individual production records in such a way as to further increase the amount of possible error, however, should, without question, be avoided.

Since it is known that the fat percentage of cows' milk decreases with the advancing age of the cow, the application of conversion factors, developed for total butterfat, to butterfat percentage will introduce an error that is always made in the same direction. Furthermore the application of those conversion factors, which were developed for total butterfat, to total milk production also introduces an error that tends to be always in the same direction. The assumption that the first lactation butterfat percentage also applies to mature cows is to give bulls credit, in mature equivalent calculations, for transmitting a higher fat percentage than is really the case. Furthermore, the application of the same factor to the first lactation milk production, in raising it to a mature equivalent, does not credit the sire with having transmitted as much total milk as he actually did transmit. The final result of such applications of the butterfat conversion factor for all three conversions is that a sire is credited with the correct amount of total butterfat but with a butterfat percentage impossible of attainment and with a total mature equivalent milk flow of less than he transmitted. These facts are apparent from a study of the following example, where a cow makes a record at 2 yrs. 6 mos. of age of 10,000 pounds of milk testing four per cent and 400 pounds of butterfat. Applying the standard U.S.D.A. Bureau of Dairy Industry butterfat factor of 1.211 to this record a mature equivalent of 12,110 pounds of milk testing four per cent and 484 pounds of butterfat is obtained. Applying the fat percentage differential of one tenth of one per cent as indicated in table 1, however, the mature equivalent butterfat percentage would be 3.9 per cent instead of four per cent. By dividing 3.9 per cent into the total mature equivalent butterfat of 484 pounds a mature equivalent milk production of 12,410 is indicated. We find then that this cow that would have been credited with 12,110 pounds of milk, testing four per cent, and 484 pounds of butterfat at maturity should actually have a mature equivalent of *12,410 pounds milk, testing 3.9 per cent,* and 484 pounds of butterfat. This difference of 300 pounds of milk, since it is always going in the same direction, cannot be ignored although it may not be statistically significant. For those agencies that include equal parent indices in proved sire reports, the difference will be slightly more important.

An even greater hazard in the failure to recognize the decline in butterfat percentage with age lies in the fact that the owners of those breeds of

cattle in which the maintenance of a minimum fat percentage is important, are lulled into a false sense of security in selecting proved herd sires. In selecting a four per cent bull to use on his herd that actually averages four per cent the prospective purchaser does not know that the bull whose dam-daughter comparison indicates a four per cent level (by present methods) is actually a 3.9 per cent bull. In fact this may be one of the reasons why, despite the efforts to select for higher test in the lower testing breeds, so little progress has been made in increasing the average butterfat percentage for these breeds even in herds where a testing program is carried on.

Any agency reporting dam-daughter comparisons on a mature equivalent basis for the evaluation of sires has assumed a serious obligation. Every effort should be made to reduce to a minimum the possibilities of errors due to method. The use of factors for both total milk production and total butterfat production, or the recognition of fat percentage differentials, properly applied if a single set of conversion factors are used, should help greatly to keep variations from the actual production trend with age at a minimum.

SUMMARY

A study of 34,176 lactation records not exceeding 305 days in length shows a definite decrease in the butterfat percentage of the milk of Ayrshire cows from the first lactation to old age that is statistically significant. Because of this decline in butterfat percentage with age it is suggested that it would be more nearly accurate to use age conversion factors for both milk and butterfat production, or to use a fat percentage differential as a correction factor when using only one set of age conversion factors for both milk production and butterfat production.

ACKNOWLEDGMENTS

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TEMPERATURE–TIME RELATIONSHIPS FOR HIGH-TEMPERATURE–SHORT-TIME STERILIZATION OF EVAPORATED MILK

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High-temperature-short-time sterilization is used commercially in this country only for canned fruit and vegetable juices. The application of this method of sterilization to the processing of evaporated milk presents certain problems, which arise chiefly from the chemical and physical instability of the product in storage. In studying these effects, which have been reported in another paper (2), the writers also obtained data on the temperature-time relationships for the death points of spores. These data are presented in this paper.

METHODS AND EQUIPMENT

The general procedure consisted of the inoculation of concentrated whole milk with washed spores of the desired level of heat resistance and the heating of the concentrate at different high temperatures for periods of seconds followed by rapid cooling. Examination of the aseptically collected milk and of plated control and heated samples after an appropriate period of incubation revealed the course of destruction of the spores.

The test organism (9499) was an unidentified sporing species isolated from spoiled, commercially canned, evaporated milk. It is a facultative thermophilic aerobe; growth optimum 37°–40° C. (98.6°–104° F.), maximum 50°–55° C. (122°–133° F.). In evaporated milk (26% solids) at 115° C. (239° F.) the thermal death time of the spores (100,000 per ml.) was approximately 14 minutes.

The spores were produced on nutrient agar slopes. After 3 weeks of incubation at 37° C., the growth—practically 100 per cent spores—was collected, washed 3 times by centrifugation with sterile distilled water, and filtered through cotton. The clumps were largely dispersed by agitating their aqueous suspensions with small glass beads. Suspensions of the spores in distilled water w re stored at 6° C. (42.8° F.).

Samples of the inoculated milk taken before and after heating were plated with glucose extract agar and the colonies counted after 48 hours at 37° C. Flasks of aseptically collected milk, tightly stoppered, were incubated at 37° C. and examined at weekly intervals for 3 months. Samples of the uninoculated milk also were plated, both before and after heating at 85° C. for 10 minutes. The concentration of viable spores in the milk before the heat treatment was approximately 100,000 per ml., of which less

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than 30 had been present prior to inoculation. Since the test spores were found to be susceptible to heat-activation,[1] the total viable count was considered to be that obtained by the plating of the inoculated milk after heating at 95° C. for 10 minutes.

The sterilizer was a Mallory small-tube heat-exchanger (3) consisting of a heating section and a holding and cooling section integrally combined and connected to a high-pressure reciprocating pump which forced the milk through the small tubes at high velocity. The temperature was raised by introducing high pressure steam through a reducing valve into the heating chamber and the holding time was varied by changing the length and diameter of the tubing through which the hot milk was forced enroute to the cooling coil.

The cooled milk was discharged aseptically into sterile bottles by means of a special collecting device; this consisted of a glass manifold which could be connected without internal contamination to the by-pass outlet of the heat-exchanger. Half-pint milk bottles and two large flasks were attached to this manifold by rubber tubing. Each container was closed with a rubber stopper fitted with two short lengths of glass tubing. One of these served as an air vent, the other was connected to the manifold by means of rubber tubing. Open ends of the sample-collecting assembly were plugged with cotton and covered with paper held in place with rubber bands.

Individual parts of the sampling assembly were cleaned, assembled, sterilized in an autoclave, carried as a unit to the heat-exchanger, and aseptically attached to the by-pass outlet. The heating and cooling coils, and each holding tube, were sterilized by hot water heated in the heating coil to 120° C. (248° F.) or higher, directed into the connecting and holding tubing and thence into the cooling coil. The latter was not surrounded by water while it was being sterilized. Means were provided for creating a back pressure in the cooling coil sufficient to insure sterility in 20 minutes.

By manipulation of pinchcocks the processed milk was directed from the main line of the assembly through the glass manifold into the sterile sample containers. When these were filled to the desired level the manifold was detached from the sampling outlet, plugged with sterile cotton, and the entire assembly carried to the plating room. Samples to be used for bacteriological examination were incubated directly or subcultured as previously described. The remainder of the samples were used in the study of the physical properties of the milk (2). With these samples the original perforated stoppers were aseptically replaced with sterile solid rubber stoppers, the bottles labeled, covered with small sterile paper bags and stored with tinned samples at 30° C. The nature and general arrangement of the processing and sampling equipment are shown in figure 1.

[1] A discussion of this subject will be prepared for publication elsewhere.

RESULTS

The essential bacteriological data are summarized in the accompanying graphs (figures 2 and 3). Figure 2 shows the minimum time in seconds required for the killing of all the test spores at four different temperatures.

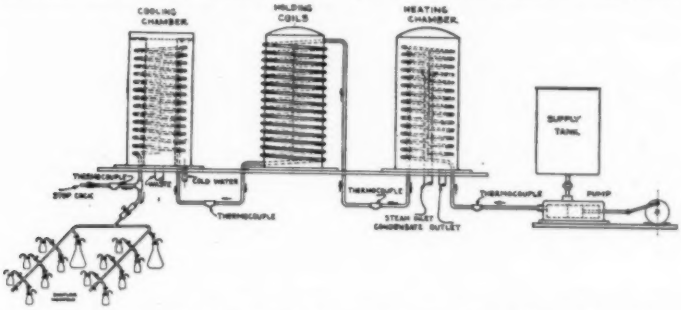

FIG. 1. Schematic drawing of the processing and sampling equipment.

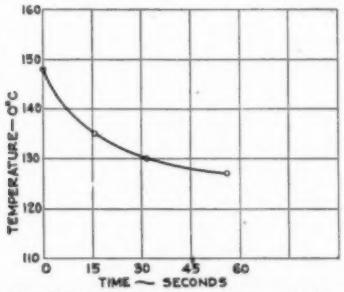

FIG. 2. The relationship between temperature and time for sterilization.

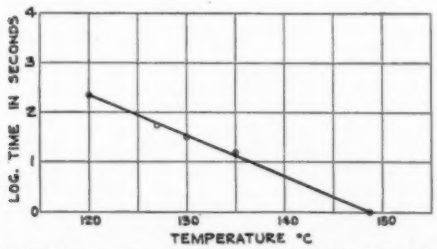

FIG. 3. The relationship between temperature and the logarithms of the sterilizing time.

Since approximately 3 seconds was required for heating and also for cooling, zero holding-time heating actually involved about 6 seconds of rapidly changing temperatures between 30° C. (86° F.) and 148° C. (298.4° F.).

This period of changing temperatures is estimated to cause less change in actual data than can be accurately plotted in the scale chosen. In view of the heat-resistance capacity of the test spores, these data afford a valid index of the sterilizing efficiency of the heat-exchanger for evaporated milk. Figure 3 shows the linear relationship between the temperature and the logarithms of the sterilizing time.

The two factors which precisely define a thermal death curve—viz., the thermal death time at a specified temperature and the thermal death curve slope (interval in temperature per log cycle)—have been utilized by Ball (1) to develop mathematical equations for estimating the lethal effect of sterilization processes. Since information is lacking concerning the constancy of the slope of the thermal death curve at temperatures above 130° C. (260° F.), the applicability of these equations to such temperatures is held to be uncertain. The small-tube, continuous-flow heat-exchanger which provides extremely rapid and uniform heating, should be useful in obtaining the necessary experimental data for the clarification of this subject.

The reported results were obtained in evaporated whole milk of 26 per cent solids content. Increasing the solids to 32 per cent slightly increased the required sterilizing time. Variations in forewarming treatment produced no measurable change in the sterilizing time. Throughout the range in treatments represented in figure 2, the color, flavor, and odor of the resulting product was superior to that of the conventionally sterilized product. The development of certain non-microbial physical and chemical changes incident to long storage presents the most serious problem in the successful application of high-temperature-short-time sterilization of evaporated milk (2).

SUMMARY

The temperature-time relationships for the destruction of spores in concentrated whole milk by high-temperature-short-time heating are given and the method described.

The required killing time is an exponential function of the temperature.

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EFFECTS OF TEMPERATURE AND TIME OF STERILIZATION UPON PROPERTIES OF EVAPORATED MILK

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The effects of high-temperature-short-time heating of milk and of its concentrate on the heat stability of the concentrate have been described in recent publications (7, 8). The work reported here deals with the high-temperature-short-time[1] sterilization of concentrated milk in its relationship to some of the properties of the evaporated product and compares these properties with those of evaporated milk made in the conventional manner.

METHODS AND EQUIPMENT

The source of milk, the standardization of the milk to a fat to solids-not-fat ratio of 1 : 2.29, forewarming, high-temperature heating, condensing, homogenizing, pilot sterilizing and cooling were as described by Webb, Bell, Deysher and Holm (8).

New facilities included means for aseptically packaging the high-short sterilized milk. They are described by Curran, Bell and Evans (2).

Viscosity measurements were made with a MacMichael viscosimeter and the values converted to centipoises. All measurements were made at 30° C., the first within 3 days after the milk was sterilized.

In preparing controls, the sterilizing temperature was 115° C. (239° F.) and the holding time 18 minutes.

The sterilizing efficiency of the high-short process for evaporated milks was determined by pretreatment inoculation of the milk with washed spores of suitable heat resistance followed by incubation or subculture of the heated samples (2).

Some of the high-short sterilized evaporated and the unsterilized control concentrates were canned and heated in a pilot sterilizer at 115° C. for various periods, cooled in a few minutes and stored at 30° C. with the other samples.

The methods of measuring color were those used by Webb and Holm (9).

RESULTS

The influence of the forewarming treatment, solids content and sterilizing conditions on the heat stability, viscosity and color of evaporated milks made from well-mixed portions of the same raw milk are shown in table 1.

The forewarming treatment had a striking effect on the heat stability of the samples. A forewarming treatment of only 65° C. (149° F.) for 10

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[1] Hereafter designated high-short sterilization.

TABLE 1

The effects of forewarming treatment, solids content, and sterilizing conditions on the heat stability, viscosity, and color of evaporated milks

Forewarmed		Total solids	Sterilized		Heat stability	Viscosity at 30° C.	Color
At	For		At	For			
°C.	*min.*	*per cent*	*°C.*	*min.*	*min.*	*centipoises*	
95	10	26.0	.....	.....	27	9.0	1
95	10	26.0	115	18.0	.....	14.5	4
95	10	32.5	.....	.....	15	.....	1
95	10	32.5	115	18.0	.....	260.0	6+
65	10	26.0	.....	.....	3	7.0	1
65	10	26.0	135	0.5	53	8.0	1
65	10	32.5	.....	.....	0	10.5	1
65	10	32.5	135	0.5	16	15.0	1+
120	4	26.0	.....	.....	84	7.0	1
120	4	26.0	135	0.5	95	8.5	1+
120	4	32.5	.....	.....	35	14.5	1
120	4	32.5	135	0.5	43	17.5	2−

minutes, although sufficient to protect the milk against the development of rancidity, did little to stabilize its concentrate to heat.

However, after this concentrate had been sterilized by the high-short method at 135° C. (275° F.) for 30 seconds its heat stability was 53 minutes instead of 3 for the 26.0 per cent evaporated and 16 minutes instead of 0 for the 32.5 per cent solids content product.

Under appropriate conditions, 120° C. for 4 minutes is an unusually effective milk forewarming treatment for increasing the heat stability of concentrated milk (8). Concentrates of this milk that contained 26.0 and 32.5 per cent solids had a heat stability of 84 and 35 minutes, respectively. After sterilization by the high-short method these values were increased only to 95 and 43 minutes, respectively.

The evaporated milk which had a viscosity of 260 centipoises at 30° C. curdled during sterilization because the time necessary to initiate coagula-

TABLE 2

The effect of heating high-short (135° C.—0.5 minute) sterilized evaporated milks in cans at 115° C. for 2, 6, 12 and 18 minutes on their viscosity and color

Milk solids	Time at 115° C.	Whole milk forewarmed at 65° C. for 10 min.		Time at 115° C.	Whole milk forewarmed at 120° C. for 4 min.	
		Viscosity	Color		Viscosity	Color
per cent	*min.*	*centipoises*		*min.*	*centipoises*	
26.0	2	8.0	1+	2	8.0	2
26.0	6	9.0	2	6	8.5	3−
26.0	12	9.5	2+	12	9.0	3+
26.0	18	10.0	4+	18	9.5	5
32.5	2	19.0	2−	2	16.0	2
32.5	6	25.5	2	6	17.5	3−
32.5	12	59.0	4	12	21.5	5
32.5	18	278.0	6+	18	27.0	7+

tion in this 32.5 per cent concentrate at 115° C. was only 15 minutes. The color value of this sample and that of the 26.0 per cent evaporated milk prepared in the customary manner was high. The color of the unsterilized milks was only slightly increased by high-short sterilization.

The effect of sterilizing conditions which are a combination of the high-short method of these experiments and of those usually practiced on the viscosity and color of the milks is shown in table 2. The high solids evaporated milk made from high temperature forewarmed whole milk, being relatively stable to heat, retained much of its fluidity even after 18 minutes in a can at 115° C. Of further interest in this table are the data which show that when the high-short sterilized milks were heated in the cans at 115° C. for 6 minutes their color was not greatly increased. Most of the

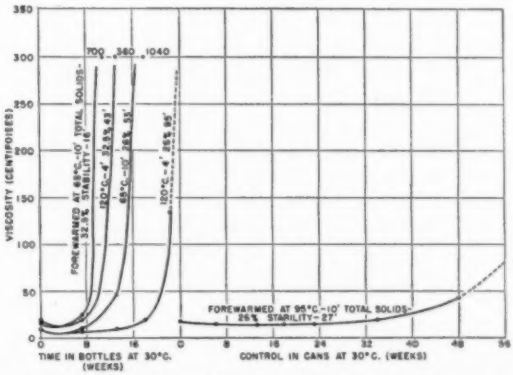

FIG. 1. Effect of widely different forewarming conditions and solids content on the viscosity of high-short evaporated milks during storage. Forewarming treatment of whole milk, solids content, and heat stability of evaporated milk are shown on each curve. Bottled concentrate was sterilized by heating at 135° C. for 30 seconds. Control concentrate of 26% total solids content was sterilized in cans by heating at 115° C. for 18 minutes.

darker color of the samples heated 18 minutes at 115° C. was imparted during the last one-third of this period (see also Webb and Holm, 9).

In figure 1 are shown the viscosity changes during storage at 30° C. in the high-short sterilized and bottled samples referred to in table 1. The contents of these bottles began to lose their fluidity in from 6 to 16 weeks, depending on the method by which they were prepared. Thereafter these milks thickened rapidly and, in the course of a few more weeks, formed a gel.

The samples referred to in figure 2 were high-short sterilized and then heated in the small cans at 115° C. for the minutes marked on each curve. These curves, together with those in figure 3 reveal not only the stabilizing effect of the additional heat treatments in the cans but the influence of initial heat stability on stability during storage.

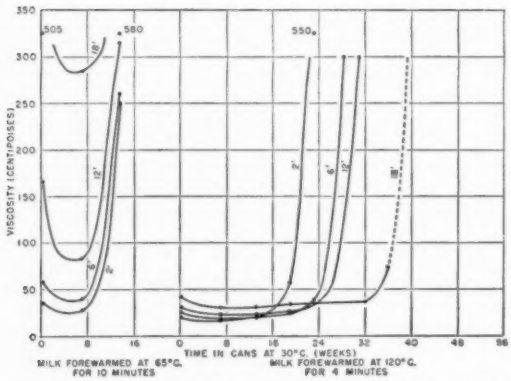

FIG. 2. Effect of time of heating at 115° C. in cans upon the viscosity during storage of high-short evaporated milks of 32.5% solids content referred to in figure 1. Minutes at 115° C. are shown on curves.

Figure 3 is similar to figure 2 except that it refers to evaporated milks of the composition of the article of commerce. The viscosity or body of the samples prepared from high-short sterilized evaporated milk of unusually high heat stability (95 minutes) increased at a relatively slow rate. The viscosity values of these samples remained low twice as long as did those of samples of lower heat stability (53 minutes) shown in the same figure.

DISCUSSION

The work reported here demonstrates the relative ease with which fresh evaporated milk of lighter color can be prepared. This lighter color was

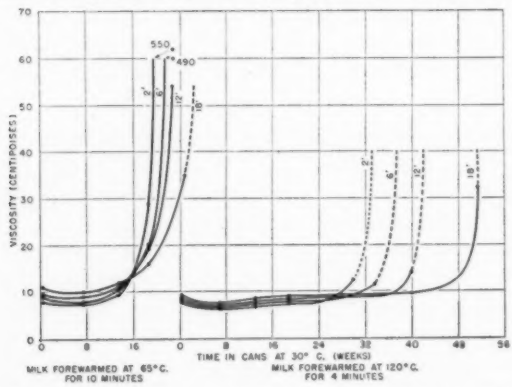

FIG. 3. Effect of time of heating at 115° C. in cans upon the viscosity during storage of high-short evaporated milks of 26% solids content referred to in figure 1. Minutes at 115° C. are shown on curves.

accompanied by a decrease in the intensity of the cooked flavor. Furthermore, these improvements in color and flavor were permanent, that is, they distinguished the aged as well as the fresh high-short sterilized samples from those sterilized by heating at 115° C. for 18 minutes.

None of the samples examined during the course of the experiments discussed in this paper had an oxidized or rancid flavor.

An important difference in the evaporated milks made by the two methods is in the properties of their cream layers. In the high-short sterilized samples, and particularly those of low heat stability, as storage changes progressed, the cream layer became jellylike, well defined, and deep. It was of short texture in that it broke cleanly and smoothly as well-firmed cheddar cheese curd does at cutting time. As the heating period in the cans was lengthened the cream layer which developed during storage was less well defined. It was softer and creamier and the fat in it could be redispersed with relative ease.

Grindrod (3) recognized the beneficial effect of additional heating of quickly sterilized evaporated milk on fat separation during storage in his U. S. Patent No. 1,714,597 (1929). On page 9, in lines 83 to 90, he said, "After such sealing, the filled cans are placed in a sterilizer of suitable form, such as now used for sterilized milk, and are given a heat treatment for say ten minutes at 230° F., which serves to destroy any accidental bacterial contamination and to bring about the colloidal adsorption which prevents separation or churning of the fat."

The high-short treated milks developed a gel which, when broken before it became firm, separated into curds and whey. As the body of the samples made in the conventional manner slowly became a gel the material held its water better than did that of the high-short samples and, when poured or stirred, was more homogeneous.

A factor which is of importance to the manufacturer of evaporated milk is the ability to control the heat stability and to a large degree thereby the body of his product. To do this the manufacturer strives to attain a concentrate which has a heat stability of a few minutes longer than to about twice that of the sterilizing period. Then, by varying the sterilizing conditions, he can approach the heat stability limit and attain a more viscous milk. The greater viscosity retards fat separation during storage and gives the appearance of richness to his product.

During high-short sterilization there is little opportunity to control body, and, through a heavier body, the extent of fat separation.

The difference in storage stability between evaporated milks made by the two methods of sterilization presumably was due primarily to the greater effect which the longer time of heating at the lower temperature had on the casein as it existed in the concentrates. The longer time of heating at the lower temperature apparently made the caseinate less hydrophylic and to this extent caused the less fluid sols to be more stable.

It is possible that the calcium and magnesium salts, because of the unique effect of heat on their solubilities, had a minor influence. Mojonnier and Troy (4) state that tricalcium citrate is more easily soluble in cold than in hot water and that after evaporated milk has aged for a considerable time there appears upon the bottom of the cans white, gritty, sand-like particles which are lime salts of citric acid or tricalcium citrate, $Ca_3(C_6H_5O_7)_2+4\,H_2O$. Sato (6) ascertained that the small white particles which he found on the bottom of a two-year-old specimen of evaporated milk were composed of tricalcium phosphate, $Ca_3(PO_4)_2$, magnesium phosphate, $Mg_3(PO_4)_2$, and tricalcium citrate, $Ca_3(C_6H_5O_7)_2$. According to Pollacci (5) one liter of rain water dissolves 0.0216 gram of tricalcium phosphate at 12.5° and 0.0120 gram at 100°. Chatterjee and Dhar (1) found that at 30°, 2.51 grams of $Ca_3(C_6H_5O_7)_2+4\,H_2O$ will dissolve in one liter of water and only 2.10 grams at 95°.

When solutions of these salts are heated, considerable time is required for attainment of the new solubility equilibrium. When concentrated milk is sterilized by the high-short method the conditions are less favorable for attainment of the new salt equilibrium than during the low-long procedure and presumably less calcium and magnesium are rendered insoluble. Hence, the tendency for the protein particles to swell and form a gel might be greater.

Experiments have been completed which differed in the high-short sterilizing treatment and other details but not in the pattern of those reported above. Holding periods of a fraction of a second, 15, and 60 seconds at temperatures of 150, 140, and 125° C., respectively, were employed. Although the results of these experiments likewise varied as to detail, they do not change the general conclusions.

SUMMARY

Highly heat stable high-temperature-short-time sterilized evaporated milks of 26 per cent solids content resembled the unsterilized product in color, were only mildly cooked in flavor, and were of light body (low viscosity). When stored at 30° C. they were of fairly satisfactory quality for only approximately 4 months.

Brief heating in cans at 115° C. increased the storage life of these high-short sterilized milks. After 18 minutes at this temperature they were as stable in storage as evaporated milk made by forewarming the whole milk at 95° C. for 10 minutes and sterilizing its 26 per cent solids concentrate at 115° C. for 18 minutes.

In the manufacture of evaporated milk, sterilization at 115° C. for 18 minutes not only destroys the contained microorganisms and affords an opportunity to control the body but it also decreases the firmness of the cream layer which forms during storage and increases the ease with which the fat in this cream layer may be redistributed in the product.

Long continuing fluidity and high heat stability in evaporated milk are not correlated. Long continuing fluidity is rather due to changes caused by heat which are associated with a darker color and a more cooked flavor.

The solution of problems associated with instability of the product on long storage must precede the commercial application of high-short sterilization in the manufacture of evaporated milk.

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A NEW METHOD FOR INDEXING DAIRY BULLS

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Dairy cattle breeders use many criteria for evaluating breeding worth in their animals. Among the best criteria and in descending order of merit, stand (A) Progeny, (B) Performance, (C) Pedigree. It is generally accepted that the best measure of an animal's breeding or transmitting value is the sort of progeny the animal begets. This is especially true in the case of dairy bulls, since they themselves yield no product. With the cow we can get performance (a record or records) and relatively few progeny. With the bull we cannot get performance in this sense but may get many progeny.

For a considerable time dairy bulls were judged on the basis of their daughters' production alone. During the past 25 years various methods of indexing dairy bulls by comparing their daughters' production with that of the bull's mates (or daughters' dams) have been proposed (1–21). Hansson, Woodward, Yapp, Gifford, Pearl, Gowen, Turner, Goodale, LaMaster, Wright, Heizer and Norton have contributed ideas on the indexing of dairy bulls. Lush (12), in 1933, discussed the general genetic problems involved in indexing including the idea of invoking regression proposed by H. W. Norton, Jr., in some unpublished data.

Heizer (9), in 1933, on the basis of his analysis of the extended records in a large Ayrshire herd, suggested the use of regression toward the herd or breed average in indexing bulls and in predicting the production of daughters from dams with records and by indexed bulls. Yapp (20), in 1938, discussed the relation of regression to selection.

Many investigators have reported daughter-dam correlations in dairy cattle both for amount of milk and butterfat test. These correlations have ranged from about 0.2 to 0.5 depending on whether they referred to individual or group correlations, the source of the data and the intensity of selection practiced on the daughters or dams, and perhaps on still other circumstances.

The writer has restudied the problem of daughter-dam correlations especially as it relates to the indexing of dairy bulls. Five of the major dairy breeds in America were included in the study which involved the following numbers of daughter-dam comparisons:

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[1] The writer wishes to thank C. T. Conklin and the Ayrshire Breeders' Association; H. W. Norton, Jr., and the Holstein-Friesian Association of America, Leonard Tufts, Dr. J. F. Kendrick and Dr. R. G. Schott for their cooperation and helpful suggestions. He is especially indebted to Dr. Jay L. Lush of Iowa State College for his constructive criticisms and guidance. Dr. Lush's paper on ascertaining the optimum regression factor for use in indexing dairy bulls is on the pages just following this article.

Ayrshire	19,885
Brown Swiss	808
Guernsey	1,754
Holstein	23,706
Jersey	1,656

First a study was made of individual records. The Ayrshire Breeders' Association made available about 3000 daughter-dam comparisons taken at random from the breed files at Brandon, Vermont; and the Holstein-Friesian Association of America made available about 3500 daughter-dam comparisons chosen at random from the breed files at Brattleboro, Vermont.

Correlation surfaces of this material were prepared and yielded the data found in table 1.

TABLE 1

Individual daughter-dam comparisons for amount of milk and butterfat test, Ayrshire and Holstein

	Mean	Standard deviation	Correlation	Regression daughters on dams
Ayrshire Milk, Dams	8,938	1,832	0.289 ± 0.017*	0.291
Daughters	8,784	1,846		
Holstein Milk, Dams	12,050	3,036	0.322 ± 0.015	0.333
Daughters	12,182	3,147		
Ayrshire Butterfat Test, Dams	4.07	0.322	0.482 ± 0.014	0.474
Daughters	4.08	0.317		
Holstein Butterfat Test, Dams	3.46	0.277	0.433 ± 0.013	0.436
Daughters	3.51	0.279		

* Figures throughout paper are standard errors.

From table 1 it is evident that individual daughter-dam correlations for amount of milk is about 0.3 and for butterfat test about 0.45. These correlations may include much or little from common environment in addition to what they include from heredity in the true sense; *i.e.*, from the fact that daughter and dam have half their genes identical and may resemble each other in the remaining half as much or little as unrelated members of the same breed would. In most cases daughter and dam are tested in the same herd. If the environment of that herd is better than average, both records are likely to be raised; if the environment in that herd is less favorable than average, both records are likely to be low. Thus the amount of the environmental contribution to the daughter-dam correlation depends both on how widely the average environment differs from herd to herd in the material being studied, and on how much influence those environmental differences have on the characteristic (milk might be more labile than test, for example) being studied.

GROUP COMPARISONS

Next a study was made of groups of dams and their daughters by individual bulls—such data as are commonly used in indexing dairy bulls. Data

TABLE 2

Group daughter-dam comparisons for amount of milk

	Number bulls	Daughter-dam comparisons	Mean milk	Standard deviation	Correlation	Regression of daughters on dams
Ayrshire	73	540	Dams 8,455 Daus. 8,142	1,172 1,207	0.479 ± 0.090	0.493
Brown Swiss	109	808	Dams 9,370 Daus. 9,606	1,350 1,467	0.547 ± 0.068	0.594
Guernsey	225	1,754	Dams 7,676 Daus. 7,730	1,010 1,139	0.617 ± 0.041	0.695
Holstein	561	4,635	Dams 11,062 Daus. 11,288	1,547 1,660	0.550 ± 0.029	0.590
Jersey	234	1,656	Dams 7,234 Daus. 7,073	1,051 1,083	0.619 ± 0.040	0.637
						Av. 0.601

printed in U.S.D.A. Miscellaneous Publications No. 522, May, 1943, provided part of the material for analysis and yielded the data listed in tables 2 and 3.

It is obvious from tables 2 and 3 that higher correlations and regressions result when animals are taken as groups, as is done in indexing dairy bulls. As individuals, the correlations for amount of milk and butterfat test average about 0.3 to 0.4. When taken as groups they rise to 0.5 to 0.6. In the groups we have not only the individual correlation but an additional amount due to the fact that these groups of dams and their daughters for the most part spend their lives on the same farm and, therefore, under very similar environments. Lush and his co-workers at Iowa have shown that there is a correlation of about 0.20 to 0.30 between cows kept in the same barn regardless of relationship.[2]

TABLE 3

Group daughter-dam comparisons for butterfat test

	Number bulls	Daughter-dam comparisons	Mean test	Standard deviation	Correlation	Regression of daughters on dams
Ayrshire	73	540	Dams 4.05 Daus. 4.16	0.177 0.194	0.466 ± 0.091	0.510
Brown Swiss	109	808	Dams 3.99 Daus. 4.04	0.222 0.232	0.605 ± 0.060	0.632
Guernsey	225	1,754	Dams 4.83 Daus. 4.91	0.256 0.262	0.446 ± 0.053	0.456
Holstein	561	4,635	Dams 3.51 Daus. 3.55	0.181 0.205	0.463 ± 0.033	0.524
Jersey	234	1,656	Dams 5.23 Daus. 5.31	0.340 0.336	0.610 ± 0.041	0.602
						Av. 0.545

[2] JOURNAL OF DAIRY SCIENCE, 17: 737–742; 18: 811–825; and 25: 975–982. See also pages 279–284 in "Milk Secretion" by John W. Gowen.

To test this matter of group correlations and regressions further (since it is so vital a matter in indexing dairy bulls) the writer secured a list of 1,095 indexed Ayrshire bulls from the Ayrshire Breeders' Association and used the Red Book Volume 14 of the Holstein-Friesian Association of America for data on 961 indexed Holstein bulls, using the records on a C basis (M.E.; 2 x's, 305 days approximately).

Correlation surfaces of these materials were prepared and yielded the data found in table 4.

It will be observed in table 4 that the Ayrshire mean milk is lower than it was in table 1. The probable reason for this is that the figures in table 4 go back over a period of 25 to 30 years, while those of table 1 are for the most recent Ayrshire records. And in test the figure for Ayrshire dams in table 4 is somewhat lower than for daughters or for dams and daughters

TABLE 4

Group daughter-dam comparisons for amount of milk and butterfat test

	Number groups	Mean	Standard deviation	Correlation	Regression of daughters on dams
Ayrshire Milk, Dams	1,095	8,451	1,116	0.571 ± 0.020	0.632
Daus.	1,095	8,203	1,236		
Holstein Milk, Dams	961	12,095	1,799	0.549 ± 0.022	0.561
Daus.	961	12,051	1,839		
					Av. 0.597
Ayrshire Test, Dams	1,095	4.02	0.187	0.448 ± 0.024	0.446
Daus.	1,095	4.07	0.186		
Holstein Test, Dams	961	3.44	0.148	0.575 ± 0.021	0.691
Daus.	961	3.47	0.178		
					Av. 0.568

in table 1. The reason for this is that table 4 includes records made by more mature cows, test dropping slightly with advancing age. The figures of this study show the present Ayrshire breed to average 8,800 pounds of 4.04 per cent milk so these figures will be used later in this article as the centers of tables for "normal expectations."

The Holstein data are all of rather recent vintage and thus need no explanation. For indexing purposes to be discussed later, we can take the present Holstein average to be 12,000 pounds of 3.46 per cent milk and we will use these figures for the centers of the Holstein normal expectation tables.

Table 4 shows that the group regressions of daughters on dams for both amount of milk and butterfat test are about 0.5 as was also shown in the lesser amount of data in tables 2 and 3. Tables 2, 3 and 4 also show that the variability (standard deviation) is reduced by about 30 to 50 per cent (contrast with standard deviation in table 1) when the material is treated in groups as is done in indexing bulls.

The matter of regression may be easily illustrated by a graph as in figure 1.

In figure 1 we have assumed a breed with an average production of 12,000 pounds. If we graph the groups of cows from 6,000 pounds to 18,000 pounds (solid line), then the average of their daughter groups will fall about on the broken line starting at 9,000 pounds and rising to 15,000 pounds. From 6,000-pound dams we "normally expect" to get daughters at the 9,000-pound level, *i.e.*, they will regress one-half the way back up to the breed average. Likewise from 18,000-pound dams we "normally expect"

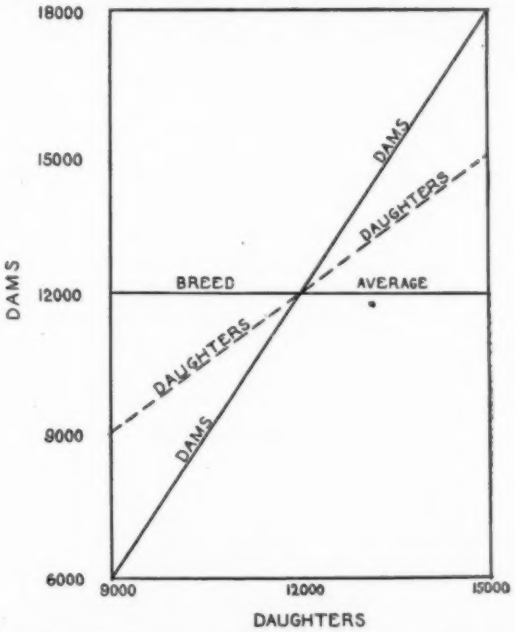


FIG. 1. Graph showing regression of 0.5 for daughters on dams. Holsteins.

their daughters to regress one-half the way back down to the breed average.

Regression, however, is not a mysterious natural law. It is due to two things: 1) the fact that phenotype does not necessarily truly mirror genotype (especially in a quality like milk production which is so prone to environmental influences) and 2) that animals producing toward the extremes are unlikely to be mated to animals as extreme as themselves.

If the breed average is 12,000 pounds of milk, we normally expect a group of daughters averaging 9,000 pounds from a group of cows averaging 6,000 pounds. Whether we would get this or not from any particular bull would remain to be seen. From a dozen bulls we might get groups of daugh-

ters all the way from 12,000 to 14,000 pounds down to 6,000 pounds, but the average of all of them would be about 9,000. There is no mysterious force, regression or any other, which will tend to move a 6,000-pound herd up to 9,000 pounds. If the owner continues to use bulls with a transmitting level of 6,000 pounds, his herd will stay at the 6,000-pound level, but if he uses average bulls it will climb up toward 9,000 pounds. Likewise an 18,000-pound herd will not automatically drop to 15,000 pounds. This herd is likely to fall back toward the breed average because its owner is likely to use average bulls. If he uses bulls with an inheritance of 18,000 pounds or more his herd will remain at 18,000 pounds or go higher.

Regression (first used by Francis Galton) is in one sense an unfortunate term because to most minds it usually connotes going backward. In the biological sense it means, according to Webster, "the correlation between parent and offspring when used as a measure of inheritance." Actually, of course, regression is the correlation times the ratio of the two standard deviations but since in much biological data the two standard deviations are approximately equal, the correlation and the regression often have approximately the same value in studies of heredity. Regression is commonly referred to as "the drag or boost of the breed." When animals get below the breed average their offspring "tend to" climb back up toward the breed average, when they get above the breed average they "tend to" fall back toward the breed average. In short, regression moves upward from below the breed average and downward from above the breed average.

Some eight or ten systems for indexing bulls have been proposed. Because of its simplicity and approximate accuracy, the one known variously as the "Equal-Parent," "Intermediate," "American" or "Yapp-Hansson" index is the one being used by the Ayrshire and Holstein breeds and the American Dairy Cattle Club (the only organizations in the United States now using bull indexes). The "Equal-Parent" index is generally calculated by finding the differences between the average amount of milk and butterfat test of a group of cows and the similar averages for their daughters by a given bull. For both amount of milk and butterfat test, if the daughters' average exceeds the dams' average, the difference is added to the daughters' average to secure the bull's "Equal-Parent" index, or if the daughters' average falls short of the dams' the difference is subtracted from the daughters' average to secure the bull's index. This system, therefore, always places the daughters just half-way (intermediate) between the dams' actual averages for milk and butterfat test, and the bull's "Equal-Parent" index for milk and butterfat test.

One form of the "Equal-Parent" index (hereafter called EP) would be: Index = 2d – m where d = daughters' average and m = dams' average.

About a dozen years ago H. W. Norton, Jr., in some unpublished work (referred to by Lush in the JOURNAL OF DAIRY SCIENCE, Vol. 16, No. 6)

suggested a use of regression of daughters on dams in computing a bull's index. His proposal was to substitute daughters' expectation (from dams of given level) for the dams' actual average production figure, and then proceed in the usual "Equal-Parent" fashion. This formula would be: Index = 2d – e where d = daughters' average and e = daughters' average expectation.

TABLE 5

Dams' actual average and daughters' expectation centered on breed averages, regression 0.5

Milk		Test	
Dams	Daughters' expectation	Dams	Daughters' expectation
m	e	m	e
Ayrshire			
12,000	10,400	4.60	4.32
.....	.....	.....	.....
8,900	8,850	4.08	4.06
8,875	8,837	4.07	4.05
8,850	8,825	4.06	4.05
8,825	8,812	4.05	4.04
8,800	8,800	4.04	4.04
8,775	8,787	4.03	4.04
8,750	8,775	4.02	4.03
8,725	8,762	4.01	4.03
8,700	8,750	4.00	4.02
.....	.....	.....	.....
6,000	7,400	3.60	3.82
Holstein			
16,000	14,000	4.00	3.73
.....	.....	.....	.....
12,100	12,050	3.50	3.48
12,075	12,037	3.49	3.47
12,050	12,025	3.48	3.47
12,025	12,012	3.47	3.46
12,000	12,000	3.46	3.46
11,975	11,987	3.45	3.46
11,950	11,975	3.44	3.45
11,925	11,962	3.43	3.45
11,900	11,950	3.42	3.44
.....	.....	.....	.....
8,000	10,000	3.00	3.23

The writer's proposal is to calculate a bull's index (hereafter called NEW[1] because it is based on *N*ormal *E*xpectation and breed averages which we intend to designate by *W*) by finding the difference between his daughters' actual and "normally expected" productions and adding this difference to the breed average. This proposal differs from the "Equal-Parent" system in that the latter method deals with the actual records of dams and

[1] It might be better to ignore the potentially unfortunate connotation of the word Regression and to call this New index what is actually is viz., Regression index.

daughters without specific reference to the breed average although, as will be shown, this feature could be included. It differs from Norton's proposal in that the latter would add the difference between daughters' actual and "normally expected" productions to the daughters' actual rather than to the breed average. Differences in formulae are:

$EP = d + d - m$	(d = daughters, m = dams)
$Norton = d + d - e$	(e = daughters' expectation)
$NEW = w + d - e$	(w = breed average)

Since the Norton index has never been used, it will not be discussed further. Its formula including the breed average would be $w - (e - m) + 2(d - e)$.

In practice the NEW index could be calculated from tables centered on the respective breed averages both for amount of milk and for butterfat test with daughters' expectation rising or falling from the breed average one-half as fast as their dams. Nuclei for Ayrshire and Holstein tables centered on the present respective breed average are shown as table 5.

For example if a group of Ayrshire dams averaged 12,000 pounds of milk, we would normally expect their daughters (by an average bull—regression 0.5) to average 10,400 pounds (e). Let's suppose they actually averaged 11,600 pounds (d) or 1,200 pounds above expectation (d – e), then this bull's index would be, $w + d - e$ or

Breed average	8,800	pounds
plus	1,200	pounds
	10,000	pounds = the bull's NEW index

If tables of normal expectation were not available, the normal expectation for any group of daughters could be ascertained by adding the respective breed averages in milk and test to the dams' average in milk and test and dividing by 2.

Similarly an optional manner of finding a bull's NEW index would be to find his EP index in the usual fashion, then add the respective breed averages to this EP index and divide by 2. In other words, the NEW method simply regresses the EP indexes half-way back to the respective breed averages.

It is the writer's opinion that a bull index should *be*

1. Sound from a genetic standpoint.
2. Easily arrived at and understandable.
3. Calculated in terms of the breed average.
4. Comparable in variability to groups of animals rather than to individuals.

and that it should *do* the following things:

5. Rank bulls in their proper order.

6. Provide a definite measuring stick for the bull's transmitting performance.
7. Provide a means for predicting future daughters' production.
8. Provide as accurate a means as possible for evaluating pedigrees.

The following discussion is a comparison of the EP and NEW systems of indexing in regard to the above 8 points.

(1) Sound from a genetic standpoint. Since the normal regressions of daughters on dams for amount of milk and for butterfat test are about 0.5 both the EP and the NEW methods are sound genetically both being based on a regression of 0.5.

(2) Easily arrived at and understandable. There would seem to be no choice between the EP and NEW systems in this regard. The NEW index can be secured either through the use of tables of normal expectations or by regressing EP indexes one-half of the way back to the breed averages as explained above. Comparable formulae are $EP = d + d - m$; $NEW = d + e - m$.

In the EP system the index is as much above or below the daughters' averages as the dams are below or above, in other words the daughters are half-way between the two parental levels. In the NEW system the index is as much above or below the breed averages as the daughters exceed or fall short of "normal expectations."

(3) Calculated in terms of breed averages. Both the EP and the NEW index systems can be calculated in terms of breed averages. The formulae are $EP = w + 2\,(d - e)$; $NEW = w + d - e$. In the writer's opinion it would be desirable for breeders to become cognizant of their respective breed averages. They would then have a definite measuring stick for their own and all other herds in the breed, so much above or below breed average. If a herd of Holsteins averaged 16,000 pounds, normal expectation would be 14,000 pounds; assume daughters averaged 15,000 pounds, breed average is 12,000 pounds, then $w = 12{,}000$; $d = 15{,}000$; $e = 14{,}000$; therefore,

$$EP = w + 2\,(d - e) \quad \text{or} \quad 12{,}000 + 2{,}000 = 14{,}000 \text{ index.}$$
$$NEW = w + (d - e) \quad \text{or} \quad 12{,}000 + 1{,}000 = 13{,}000 \text{ index.}$$

(4) Comparable in variability to average of groups of cows rather than to individual records. In the writer's opinion this would be desirable because indexes are computed from groups of cows and their daughters and because the index may be used as one limit, the group average (dams) as the other to predict the probable level of production of the resulting daughters. In pedigree evaluation, we have learned by experience to discount the extremely high or low records of cows, to reduce the variability in a general way. It seems likely that we must learn to do the same sort of thing with EP indexes. The NEW method of indexing bulls does this automatically, since it reduces the EP indexes above the breed average and increases those below the breed average, the NEW index being only one-half as far removed

in either direction from the breed average as is its corresponding EP index. To change any EP index to NEW index, we can simply add the breed averages to the former, divide by 2 and we have the latter.

The following table shows the variability of individuals, groups, EP indexes and NEW indexes for the Ayrshire and Holstein breeds.

It is seen from table 6 that the variability of the NEW index method is in keeping with that found in groups while the variability of the EP index method is in keeping with that found in individuals. Since in all indexing and use of indexes individuality is necessarily sacrificed to the group average, the writer believes the NEW method is to be preferred over the EP in this regard.

(5) Rank bulls in their proper order of production transmitting merit. It is well to bear in mind that no system of indexing can be any better than

TABLE 6

Standard deviations of daughters, dams, EP and NEW indexes

	Ayrshire				Holstein		
	No.	Milk		Test	No.	Milk	Test
Individuals	(2,973)	Dams	1,832	0.322	(3,446)	3,036	0.277
		Daus.	1,846	0.317		3,147	0.279
Groups	(1,095)*	Dams	1,116	0.187	(961)†	1,799	0.148
		Daus.	1,236	0.186		1,839	0.178
EP indexes	(1,095)		2,108	0.377	(961)	2,986	0.301
NEW indexes	(1,095)		1,054	0.188	(961)	1,493	0.150

* 29,324 individuals.
† 31,050 individuals.

the records on which it is based. If the daughters of bull A are fed and cared for on a higher plane than those of bull B and the person making the rating does not know this, or knowing it makes no allowance for it, then bull A is going to appear in a better light than bull B. The environment of both the cows and their daughters will affect the size of any bull's index. An index, in other words, is a relative, not an absolute, matter, made up of items of inheritance and items of environment. In the discussions in this paper we are of necessity assuming comparable environments.

Bulls can be ranked in a variety of ways. The writer thinks that from a production standpoint, it is best to rank Ayrshires, Brown Swiss or Milking Shorthorns in terms of 4 per cent fat corrected milk (Gaines' formula—0.4 amount of milk plus 15 times total fat). The corresponding figures for the other principal dairy breeds are Holstein (3.46 per cent test), 0.435 amount of milk plus 16.33 total fat; Jersey (5.26 per cent test), 0.336 amount of milk plus 12.62 total fat; Guernsey (5 per cent test), 0.35 amount of milk plus 13 total fat.

Here are EP indexes for 3 Ayrshire bulls:

Bull A	12,740	lbs.	milk	3.87	per cent	493	lbs. butterfat
Bull B	12,158	"	"	4.04	"	492	" "
Bull C	11,545	"	"	4.47	"	516	" "

In amount of milk they rank A, B, C; in test they rank C, A, B; in total butterfat they rank C, A, B. A consensus of these three rankings would also place them C, A, B. The 4 per cent fat corrected milk of the above three EP indexes are:

A 12,491 C 12,358 B 12,255

and the same figures for the NEW indexes are:

A 10,698 C 10,564 B 10,537

The EP and NEW systems will rank any given series of bulls in the same order since both systems are based on a regression of 0.5. EP indexes above the breed average (as in the example just cited) will be reduced, those below the breed average will be increased by the NEW method since the variability of the NEW method is just half as great as that of the EP.

(6) Provide a definite measuring stick for a bull's transmitting performance.

In this respect the NEW index method would seem to have two distinct advantages over the EP method. In the first place the NEW index provides an immediate and clear-cut evaluation of any bull's production-transmitting ability in terms of the respective breed average. A Holstein NEW index of 14,000 pounds of 3.66 per cent tells one at once that this bull's daughters exceeded "normal expectations" by 2,000 pounds and 0.2 per cent since 14,000 pounds, 3.66 per cent test is 2,000 pounds and 0.2 per cent test above the present breed average of 12,000 pounds, 3.46 per cent test. And secondly, the NEW method avoids a possible ambiguity present in any system based on a comparison of dams' and daughters' actual production. The EP method compares dams' and daughters' actual production so that if in Holsteins the dams averaged 8,000 pounds and the daughters 9,000, the bull gets a rating of 1,000 plus, and an EP index of 10,000 pounds. But from 8,000-pound Holstein dams, we normally expect 10,000-pound daughters so that this bull failed by 1,000 pounds to get his daughters up to normal expectations. Compared to an average Holstein bull, his rating is 1,000 minus and his NEW index is 11,000 pounds. In the NEW method which compares daughters' actual with their normally expected production, there should be no ambiguity in the pluses and minuses secured since the comparison tells directly whether the bull is better or worse than an average bull and how much better or worse.

Stating the difference between daughters and dams as simple pluses or minuses does not provide a necessarily accurate description of any bull's breeding worth because there is no standard point of reference. Since the normal expectation for daughters from dams below the breed average

is upward, bulls used in low producing herds generally show an increase of daughters over dams, these bulls thereby getting a plus or positive rating in dam-daughter comparisons. On the other hand, the normal expectation from dams above the breed average is downward so that bulls used in high herds generally show a decrease in their daughters, these bulls thereby getting a minus or negative rating in dam-daughter comparisons. If many breeders focused major attention on just the increases or decreases of daughters compared to dams, they would generally be favoring all bulls used or proved in low producing herds and rejecting bulls used or proved in high producing herds. If this happened the breed (and its breeders) would be harmed. Actually ½ the bulls used in low producing herds and ½ of those used in high producing herds should be favored and the other half of each rejected. Most of the bulls used in low producing herds will show an increase of daughters over dams, but only that half of the bulls whose daughters exceed normal expectations should be favored. Most of the bulls used in high producing herds will show a decrease of daughters compared with dams, but the half of these bulls whose daughters exceed normal expectations should be favored and only the other half rejected. In terms of indexes, Holstein bulls with indexes below 12,000 pounds of 3.46 per cent milk should be rejected and those above these figures favored. The amount by which a Holstein bull's NEW index exceeds 12,000 pounds of milk and a 3.46 per cent test measures directly his merit from a production standpoint. Comparable figures for Ayrshires are 8,800 pounds of 4.04 per cent milk.

(7) Provide a means for predicting future daughters' production.

The writer made a brief study of the predicting value of indexes when used in conjunction with the average production level of the bull's mates. In order to do this, 103 Ayrshire bulls were selected at random. All of these bulls had 15 or more daughter-dam pairs, they averaged 35 daughter-dam pairs. Indexes for each of these bulls were calculated on the basis of their first 10 daughter-dam pairs. For each bull this index was used in conjunction with the average production of his later mates in order to provide a prediction for the later daughters. The prediction could then be compared with these later daughters' actual average production. Since both the EP system and the NEW system are based on a regression of 0.5, the misses of prediction from actual were the same on the average, and for these data the average errors were about 700 pounds of milk and 0.12 per cent in test with the ranges running from 0 to 2,400 pounds of milk and 0 to 0.45 per cent test.

The Prediction formulae are:

0.5 EP Index + 0.5 Dams' average Production.
NEW Index + 0.5 Dams' − 0.5 Breed averages.

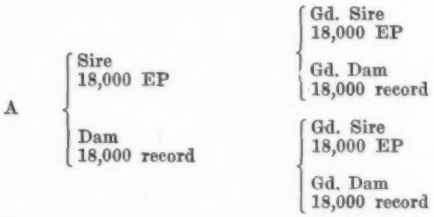
The average production of the first 10 daughters in this material gave practically as accurate a forecast of future daughters as either EP or NEW indexes used in the appropriate manner in conjunction with later mates' records. The average error using daughters alone was about 800 pounds of 0.13 per cent milk and with about the same ranges of error as found with indexes. For 86 of these 103 bulls which were used in only one herd, the average error in prediction was a little less than 700 pounds and 0.12 in test. For the remaining 17 bulls which were proved in one herd and then transferred to other herds, the average error was a little over 900 pounds and 0.14 per cent test. It would, of course, be erroneous to conclude that a bull will not transmit as well in the second herd as he has done in the first. He may transmit worse, but, of course, he may transmit better. What he appears to do will depend a lot on the environmental levels in the two herds concerned. It also will depend a lot on the genetic levels in the two herds. The genetic make-up of the cows in the second herd may not be as good a "fit" for the bull as was that of the cows in the first herd. On the other hand, of course, it may be better.

We should not confuse the matter of predicting future daughters with that of evaluating bulls. Daughters alone will predict future daughters, especially if the future daughters are to be produced in the same herd and out of much the same kind of dams, but daughters alone will not distinguish between or among bulls because the level of the dams' production does influence their daughters' production. We might have two groups of Ayrshire daughters both averaging 9,200 pounds of milk, but the sires of these 2 groups of daughters are not necessarily similar in their breeding powers. If bull A's mates averaged 7,000 pounds, we would expect their daughters to average half-way up to 8,800 or at the 7,900 pound level—they actually averaged 9,200, so bull A is 1,300 pounds better than an average bull in milk transmitting ability. If bull B's mates averaged 11,000 pounds, we would expect the daughters to average 9,900 pounds, but they too did 9,200 pounds, so bull B is 700 pounds below an average bull. These 2 bulls differ by 2,000 pounds of milk although their respective daughters' averages were the same.

(8) Provide as accurate a mean as possible for evaluating pedigrees.

The problem of evaluating the probable genetic worth of any animal from its pedigree is a difficult one at best, since pedigrees as currently written include only the selected direct ancestors and in most instances include only the most favorable data on these animals. Added to these man-made handicaps is the biological fact that inheritance is a halving and sampling process so that even though one knew a pedigree completely in terms of indexes and records, both for the direct and collateral relatives, he still would not know, except by testing and indexing, what sort of a sample half of each parent's inheritance the animal in question received and how they "nicked."

Since the direct ancestors are likely to have been carefully selected the cows' records and the bull's indexes are likely to be above the breed average in perhaps most instances. Experience has taught us to discount in a general way the extreme variations from the average which we find in the records of the cows in any pedigree. It seems probable that we would also have to learn in time to discount somewhat the EP indexes. If, for example, we had a Holstein pedigree like the following schematic pedigree what deductions would we be justified in making about genetic production level of Animal A?



Encountering the figure 18,000 all through this pedigree has a tendency to make one think that this animal must have an inheritance at about that level. However, it seems doubtful that we would be justified in ascribing an inheritance of 18,000 to Animal A although, of course, chance may have provided this or possibly even more. We now know that these 18,000-pound EP indexes indicate that these bulls' daughters produced 3,000 pounds more than normally expected since 18,000 is 6,000 above the Holstein breed average of 12,000. The more cautious among us would feel that we should at least moderate the cow's record in the schematic pedigree shown.

In terms of the NEW index these 18,000-pound EP indexes become 15,000, which has the advantage of informing us that the daughters of these bulls produced 3,000 pounds more than normally expected at whatever level their dams may have been. We can, if we like, also regress the cows' records through which they also become 15,000. In the writer's opinion, the regressed cows' records and the NEW indexes of 15,000 pounds is a more probable estimate of the genetic worth of Animal A than that likely to be derived from the actual records and the EP indexes. At least it might be a welcome change to err occasionally on the safe side.

SUMMARY

Individual regression of daughters on dams in dairy cattle is of the order of about 0.3 for amount of milk and 0.45 for butterfat test.

Group regressions are of the order of 0.5 to 0.6 both in amount of milk and butterfat test.

The "Equal-Parent" index is based on a regression of 0.5 for milk and butterfat test, but this fact is perhaps not generally appreciated,

nor are the respective breed averages generally used in computing EP indexes. The "Equal-Parent" index formula using normal expectation and breed average is $w + 2(d - e)$ where w = breed average, d = daughters' average, e = daughters' expectation = $\frac{w + \text{dams' ave.}}{2}$.

A NEW method of indexing, based on normal expectation and breed average, is suggested herein, its formula being $w + d - e$.

The NEW method compares daughters' actual production with their normal expectation rather than with their dams' actual production.

The variability of NEW indexes is of the same order as is that of groups of cows.

The variability of EP indexes is of the same order as is that of individual cows.

Either EP or NEW index method will place bulls in the same order of rank from highest to lowest.

The NEW index makes it possible to ascertain a bull's worth from a production standpoint by comparing the index directly with the respective breed averages, so much better or worse than breed average, through its incorporation of "normal expectation" as a measuring stick of any bull's transmitting performance.

Either the EP or NEW index system used in the appropriate manner with the average record of a group of cows will predict the production of future daughters reasonably accurately and perhaps a little more accurately on the average than will the average of an earlier group of daughters. Daughters' records alone, however, are not a safe guide to the genetic level of a bull or at least not as good as indexing, which automatically includes a consideration of the mates' level of production; an important item so far as their daughters' ability is concerned.

The NEW method of indexing would appear to make pedigrees look more nearly like what they are genetically than does the EP method. It would provide a measure of conservatism so often and so badly needed in pedigree writing and interpretation.

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THE OPTIMUM EMPHASIS ON DAMS' RECORDS WHEN PROVING DAIRY SIRES*

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INTRODUCTION

Nearly all of the proposals for expressing numerically the transmitting ability of a dairy sire are special forms of the general equation:

$$I = a + c(X - bY) \qquad (1)$$

Where I = the index or measure used for comparing one sire with another.
a = a constant which brings the average of the whole group of indexes to the desired level but does not alter the difference between any two sires.
c = a constant which can be used to expand or contract the variability of I without changing any correlation between it and other variables.
X = the average record of the daughters of the sire.
Y = the average record of the dams of those daughters.
b = a constant which determines the relative emphasis on Y as compared with X.

When only the average of the daughters is used as the proof of a sire, equation (1) becomes: $I = X$; *i.e.*, a and b are each zero while c is 1.0. At the other extreme when the sire proof is considered to be simply the increase or decrease of his daughters over their dams, a is zero but b and c are each 1.0, whence $I = X - Y$. The most widely used sire index (known by various names, such as intermediate, equal-parent, modified Mount Hope, etc.) sets a equal to zero but b to 0.5 and c to 2.0; *i.e.*, $I = 2(X - 0.5Y)$. The recent proposal[1] by V. A. Rice of a "NEW" index is simply to let $c = 1.0$, $b = 0.5$, and a = b times the breed average; whence $I = 0.5$ (breed average) $+ X - 0.5Y$. Turner long ago (page 24 in Missouri Research Bulletin 79 in 1925) proposed to let $I = \frac{100}{85}(X - 0.15Y)$; *i.e.*, a = zero, $b = 0.15$, and $c = \frac{100}{85}$. These examples show what diverse kinds of indexes are all included as special cases of equation (1).

The real accuracy of an index is measured by its correlation with the true transmitting ability (G) of the sire for which it is computed. The amount of improvement made in the offspring by selecting bulls with equal intensity, but according to I_1, to I_2, . . . or to I_n, is strictly in proportion to r_{GI_1}, r_{GI_2}, . . . or r_{GI_n}. The size of b affects r_{IG} but a and c do not.

The object of the present paper is to show what value of b will make r_{GI} as large as is possible for any index of the type described by equation (1). Also some related problems of using an index are discussed. These ideas

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[1] See preceding paper, this issue.

and findings arose largely as a result of discussions with Professor V. A. Rice about his "NEW" index. Helpful suggestions from him and the use of his data for reference are gratefully acknowledged, but he is not to be held responsible for the conclusions or interpretations in the present article.

PREDICTING G FROM Y AND X

Perhaps the simplest derivation of (1) is the ordinary multiple regression equation for predicting G from Y and X. The path coefficient diagram for that, and the pertinent formulas for the best possible prediction of G from X and Y jointly, are shown on the left in figure 1.

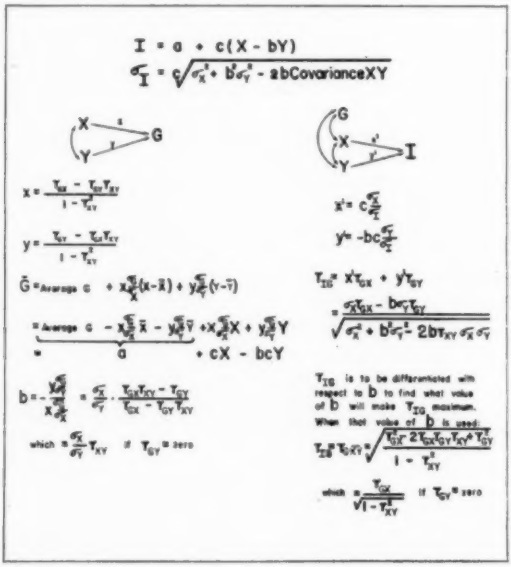

FIG. 1. Biometric relations between daughter average (X), average of mates (Y), and breeding value (G) of sire. Left: Predicting G from X and Y. Right: Correlation between G and any index (I) which is the sum or difference of any multiple of X and any multiple of Y with or without the addition or subtraction of any constant.

If r_{GY} is zero, the formula for b simplifies greatly to: $r_{XY}\frac{\sigma_X}{\sigma_Y}$, . . . , *i.e.*, to $\frac{\text{Covariance XY}}{\text{Variance Y}}$. That is, the optimum value of b is the regression of X on Y, as Rice maintains. If r_{GY} is a small positive, the optimum value of b will be somewhat less, as is shown more clearly by rewriting the formula for b (figure 1) as follows:

$$b = \frac{\sigma_X}{\sigma_Y}\left[r_{XY} - \frac{r_{GY}(1-r^2_{XY})}{r_{GX} - r_{GY}r_{XY}}\right]$$

The last term within the brackets goes to zero when r_{GY} does but must have

a positive value when r_{GY} does, since r_{GX} is practically certain to be considerably larger than r_{GY}.

The r_{GX} will be positive and of considerable size because each daughter gets half of her G as a sample half of her sire's G. Each daughter's record (O) is partly determined by her own G. Many of the other factors which can make her record large or small will be random from one daughter to another and hence will tend to cancel each other in the average (X) of several daughters. The relation between r_{GX} and r_{GO} is as follows:

$$r_{GX} = r_{GO}\sqrt{\frac{n}{1+(n-1)w}}$$

where there are n daughters and the correlation between the records of paternal sisters is w. In most dairy data collected from many different herds but analyzed as a single population, w is around 0.2 to 0.3, much of this coming from environmental differences between herds, although w also includes r^2_{GO}. Hence in most data used for proving dairy sires r_{GX} will be something like 1.5 to 2.0 times as large as r_{GO}. Reasonable values for r_{GO} (approximately half the square root of the heritability of differences between individual cows) in most dairy data are around 0.2 to 0.3 for quantity of milk or fat and around 0.3 to 0.4 for test.

For r_{GY} to have a positive value requires that there be a general tendency for the breeders who already have high producing cows to try harder than average, and for the breeders who have cows with low records not to try as hard, to get good bulls to mate with them. Further, such a difference in efforts would produce a positive r_{GY} only to the extent that the breeders estimate correctly the breeding values of the bulls at the time of choosing. Presumably there is some difference of this kind in the efforts made but this gives r_{GY} only a very small positive value because the correlation between the real transmitting ability of an untried young bull and the purchaser's estimate of that from the bull's pedigree, or from other information available when the bull is first put to work, is generally small. We shall not be far wrong if we proceed on the assumption that r_{GX} is much larger than r_{GY} although the latter may not be quite as low as zero.

How a positive correlation between G and Y could lower the proper value of b is readily understandable when one reflects that if those breeders whose herd averages are already high do generally succeed in buying young bulls with better-than-average breeding value, then a man seeking to find the best young bulls will have some degree of success if he does nothing but choose the bulls being used in herds which already had better-than-average production at the time those bulls were introduced. This is the line of thought we follow when we sometimes infer that a young bull bought for use in a high-producing herd is probably an exceptionally good bull or he would not have been selected for use in that herd. (Of course we are often wrong in such an inference, but there may well be a gambler's margin in favor of

it.) Under such conditions Y becomes a positive indicator of G in its own right and not merely a negative indicator, useful for discounting the effects of environmental differences from herd to herd and the effects which genetic differences between groups of mates have on the records of their daughters, which is its usefulness when r_{GY} is zero.

MAXIMIZING THE CORRELATION BETWEEN I AND G

The optimum value of b can also be found, by setting up the equation for r_{GI} as indicated on the right side of figure 1, differentiating it with respect to b, and then finding what value of b will make that differential equal to zero. That value of b turns out to be the same as is shown on the left side of figure 1, as of course it should be. The two ways of finding the optimum value of b are the same in principle.

ACTUAL VALUES FOUND FOR b

The values found by Rice for the regression of X on Y for milk in seven sets of data ranged only from 0.49 to 0.70 with an unweighted average of 0.60. For fat test the same sets of data yielded values ranging from 0.45 to 0.69 with an average of 0.55. Using 0.5 for b in dairy data will be nearly correct, especially if r_{GY} has some small positive value. On page 33 of the report of the New Zealand Dairy Board for 1943 a table of expectations for fat production indicates that the regression of X on Y (the proper value of b if r_{GY} is zero) in those data is about 0.58 to 0.62. This table is based on 20,150 daughter-dam pairs which were used in proving 1395 sires. Parenthetically it may be noted that, since the observed regressions are a little larger than 0.5, the daughter-dam difference seems just a shade more accurate as a sire index than the daughter average alone.

GAIN FROM CONSIDERING THE RECORDS OF THE MATES

The amount of improvement made in the next generation by selecting on the basis of I is $\frac{r_{GI}}{r_{GX}}$ times the improvement to be made by selecting (with the same intensity) for X alone. If r_{GY} is zero, this factor reduces to $\frac{1}{\sqrt{1-r^2_{XY}}}$ which in Rice's data has values ranging from 1.14 to 1.27, with an unweighted average of 1.21 for milk, and from 1.12 to 1.26 with an unweighted average of 1.18 for test. Making some rough allowance for r_{GY} having a small positive value and for the fact that in actual practice the value used for b will not always be the exact optimum value for that particular set of data, the use of I would make improvement from sire selection something like 12 to 20 per cent faster than if X were used alone. Thus the gain from using properly the records of the mates along with the records of the daughters when proving a sire is not extremely large in dairy data, although it certainly is real.

It is sometimes argued that the gain from including the mates is not enough to balance the loss from excluding those daughters which are out of untested dams. For this to be true would require that there be few daughters out of tested dams, that there be many out of untested dams, and that the correlation between the records of daughters of the same bull be low. If this latter correlation is as low as 0.24 and bulls are selected on the records of their daughters alone, progress will be 11 per cent faster when they have ten daughters than when they have five; if the correlation between daughters is + 0.30, the corresponding gain will be 9 per cent instead of 11, while with a correlation of + 0.36 it will be increased only 7 per cent, and with a correlation of + 0.42 it will be increased only 6 per cent. The above correlations are about what exist between paternal sisters in various aspects of Rice's data on Ayrshires and Holsteins. Therefore the loss from omitting entirely the daughters from untested cows would rarely equal the gain to be had by considering Y properly, even if that required omitting half the daughters. Moreover, where the record of a mate is missing, one could substitute almost as well in the index the average of the other mates or (better still) the average of that daughter's contemporary herd mates who are not by the same sire. With the spread of herd testing, as contrasted with testing only selected individuals, the proportion of daughters who are out of untested dams becomes ever smaller, more of the mates having been tested themselves as daughters in the proving of some earlier sire.

It thus appears that almost the only cost of getting the extra 12 to 20 per cent of progress to be had by including the records of the mates is the clerical cost of assembling and computing their records.

CAUSES OF THE CORRELATION BETWEEN X AND Y

The correlation between the records of individual daughter and dam has generally been reported as of the order of + 0.3 to + 0.4 in most studies of data collected from many different farms but analyzed as a single population. Why such a correlation will usually be different from the r_{XY} which describes the data as they actually are *grouped* in the proving of sires is explained as follows. Figure 2 shows, in terms of path coefficients, how r_{XY} is constituted. The letters have the following meanings:

O = the record of a daughter.
D = the record of a mate.
r = the correlation between the record of a daughter and the record of her own dam.
v = the correlation between the record of a daughter and the record of a mate of her sire other than her own dam.
u = the correlation between the records of two mates of the same sire.
w = the correlation between the records of two daughters of the same sire.

In the numerator of r_{XY} (formula shown in figure 2) v occurs n – 1 times as often as r. The denominator starts out as 1.0 when n = 1 but, as n becomes

indefinitely large, this denominator tends toward n times the geometric mean of u and w, *i.e.*, toward $n\sqrt{uw}$. It seems simplest to think of r_{XY} as a complex average consisting roughly of one part r and n – 1 parts $\frac{v}{\sqrt{uw}}$. Most of this shift of r_{XY} from r toward an expression which is mainly dominated by v, u, and w, is usually accomplished by the time n is as large as five. The regression of X on Y is $\frac{\sigma_O}{\sigma_D} r$ when n = 1 but tends toward $\frac{\sigma_O}{\sigma_D} \cdot \frac{v}{u}$ as n becomes indefinitely large.

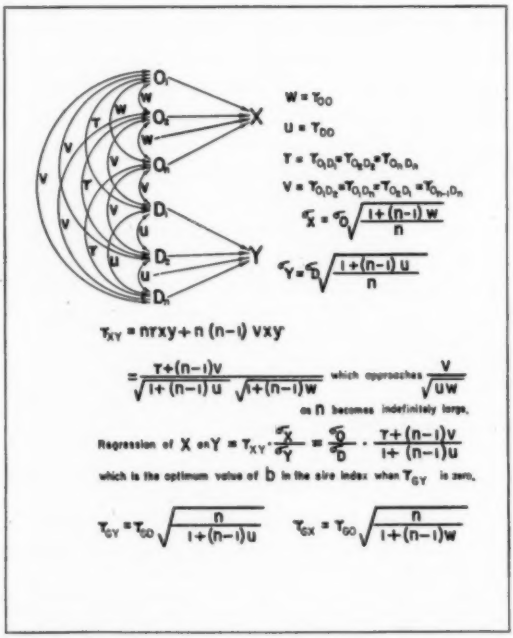
W = r_OO
U = r_DD
r = r_O1D1 = r_O2D2 = r_OnDn
v = r_O1D2 = r_O1Dn = r_O2D1 = r_OnDn-1
σ_X = σ_O √(1+(n-1)w / n)
σ_Y = σ_D √(1+(n-1)u / n)
r_XY = nrxy + n(n-1)vxy
= (r+(n-1)v) / (√(1+(n-1)u) √(1+(n-1)w)) which approaches v/√uw as n becomes indefinitely large.
Regression of X on Y = r_XY · σ_X/σ_Y = σ_O/σ_D · (r+(n-1)v)/(1+(n-1)u)
which is the optimum value of b in the sire index when r_GY is zero.
r_GY = r_GO √(n/(1+(n-1)u))
r_GX = r_GO √(n/(1+(n-1)w))

FIG. 2. Biometric relations between X and Y, showing how r_{XY} is constituted of r, v, u, and w, and may be very different from r.

In proving dairy sires, n has a minimum value of five (in the Dairy Bureau procedure—six, ten, or more in various of the registry association procedures), but is usually variable in any list of proved sires from which r_{XY} may be calculated. That is, sires which have been proved on exactly five daughter-dam pairs will be included in the same list with sires which have been proved on six, seven, or more pairs. Variations in n cause r_{XY} or b or σ_X^2 or σ_Y^2 to shift from one limiting value toward another in proportion to the changes in the reciprocal of n. Therefore, the harmonic mean[2] of n

[2] The harmonic mean of n is the n which has a reciprocal equal to the mean of the reciprocals of the actual n's.

should be used when analyzing into their constituent parts (r, v, u, and w) the r_{XY}, b, σ_X or σ_Y computed on a population of proven sires in which n was a variable. The harmonic mean will be less—sometimes considerably less—than the arithmetic mean. For example, the first 220 indexed sires in Volume 14 of the Holstein-Friesian Red Book had n's varying from 6 to 83, although for half of them n was 12 or less. The arithmetic mean was 15.2 while the harmonic mean was 11.2. For the first 152 Holstein proved sires in Misc. Pub. 522 from the U. S. Dept. of Agr. the arithmetic mean was 8.77 but the harmonic mean was 7.60. Here n ranged from five to 35 but half the sires were proved on seven pairs or less. Among the 73 Ayrshire proved sires listed in the same publication, the arithmetic mean was 7.40 and the harmonic mean was 6.88.

In table 1 are shown the values for u, w, and v computed from the data Rice shows in his tables 1 and 4. Because the statistics on X and Y (Rice's

TABLE 1

The ingredients of r_{XY} in V. A. Rice's data on Holsteins and Ayrshires

Statistic	Milk		Test	
	Ayrshire	Holstein	Ayrshire	Holstein
r[1]	0.29	0.32	0.48	0.43
v[2]	0.26[5]	0.18	0.12	0.18
u[3]	0.36[5]	0.28	0.28	0.22
w[4]	0.47[5]	0.28	0.28	0.36
2(r − v)	0.06[6]	0.29	0.72	0.51

[1] As given by Rice.

[2] Computed from the values of r_{XY} in Rice's table 4, substituting the values given for r in his table 1 and the values computed here for u and w.

[3] Computed from the formula: $\frac{\sigma_Y^2}{\sigma_D^2} = \frac{1+(n-1)u}{n}$.

[4] Computed from the formula: $\frac{\sigma_X^2}{\sigma_O^2} = \frac{1+(n-1)w}{n}$.

[5] Somewhat inflated because the data in Rice's table 4 include a considerable time trend.

[6] The correct figure here will be larger than this by about twice the size of the bias mentioned in footnote 5.

table 4) came from a slightly different sample of Herd Improvement Registry data than the statistics on O and D and because in dairy data the standard deviation tends to vary with the mean, Rice's observed $\frac{\sigma_Y}{\sigma_D}$ and $\frac{\sigma_X}{\sigma_O}$ were multiplied by the ratio of the corresponding means before computing u and w. Even after this correction, the figures for u, w, and v are still inflated (as compared with r which comes wholly from Rice's table 1) wherever the data from Rice's table 4 covered a longer period in which there was a marked time trend. This seems to have been important only for the Ayrshire milk. The data concerning Ayrshires in table 4 were collected over a period of 25 or 30 years, whereas the Holstein data go scarcely half that far

back. For Ayrshire milk the time trend was marked, since the means in Rice's table 1 are 7.1 per cent larger for daughters and 5.8 per cent larger for dams than the corresponding means in his table 4. For Ayrshire test and for the Holstein data the time trend was too small to have much effect on the present analysis, the maximum increase of any of these means in his table 1 over the corresponding mean in his table 4 being only 1.2 per cent. For computing the u, w, and v shown here in table 1, the observed harmonic mean of 11.2 was used for n in the Holstein data and 11.5 was used in the Ayrshire data. (The Ayrshire arithmetic mean actually was 13.39 but the distribution of n was not available for computing the harmonic mean directly.)

Causes of r, u, v, and w

Figure 3 shows how r, u, w, and v are caused partly by differences in breeding value and partly by differences in environment. Environment is used here to include all other causes of variation in the records except differences in the genetic value of the cows which made them.

The meaning of the symbols is as follows:

g^2 is the fraction of the phenotypic variance (σ_O^2 or σ_D^2) due to additively genetic differences between individual cows.

e^2 is the fraction of the phenotypic variance which is not additively genetic.

d is the genetic correlation between mates of a sire. It has a moderate positive value because some of the mates are related to each other and also because some breeders try harder than others to breed and select for high production.

m is the average genetic correlation between the sire and a mate. It will be very little above zero, since most breeders try to avoid even mild inbreeding. Assortive mating on somatic likeness must be indirect since the male cannot exhibit the characteristic himself. Hence assortive mating can contribute but little to m. Moreover assortive mating is not extreme for these characteristics, since no one tries intentionally to mate low producing cows to bulls with unusually low production in their pedigrees.

r_{EE} is the correlation between the non-genetic causes of variation for the individual denoted by the subscripts. It has a moderately large positive value because herds differ much from each other in their management, as well as in uncontrolled environmental conditions such as weather, condition of pastures, etc. Generally r_{EE} will be larger between daughters than between mates, or than between a daughter and a mate, because the daughters' records are more nearly contemporaneous and thus are subject to more nearly the same peculiarities of management and weather or other environment.

r_{GE} exists only to the extent that the herds with the highest intrinsic breeding values are also fed and managed better than the average herd, while herds with low intrinsic breeding values are fed and managed less well than average. There may well be some of this in dairy data but r_{GE} must be small because of the uncertainty concerning the breeding value of the average animal while it is yet alive and because no one intentionally tries to collect and breed low producers. The G and the E in r_{GE} pertain to different individuals.

The environmental terms and the terms for cross-correlations between genetic and environmental causes of variation (figure 3) are almost the same

in r as they are in v, except when a sire is proved in two or more herds. In such cases the environmental term included in r is certain to be larger than the corresponding one in v. Because their other terms are so nearly the same, subtracting v from r leaves a remainder which comes close to equalling $\frac{g^2(1-d)}{2}$. Doubling this and then making allowance for d yields an estimate of the heritability of differences between records of mates of the same sire. Figures for $2(r-v)$ are shown in the bottom line of table 1. Dividing these by something like 0.85 to 0.95 (to allow a reasonable amount for d)

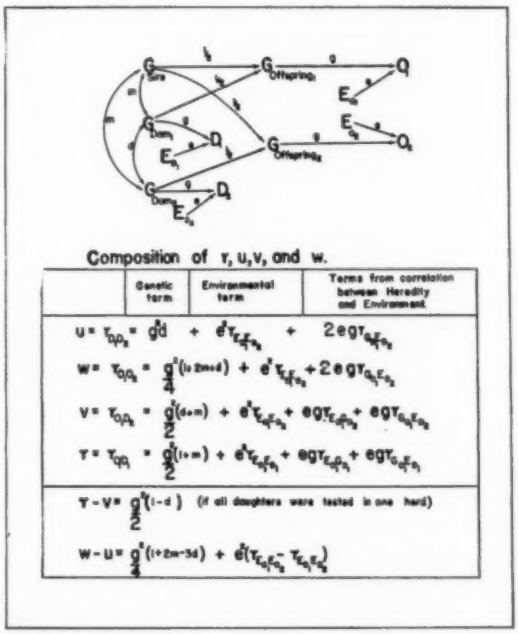
Composition of r, u, v, and w.
Genetic term
Environmental term
Terms from correlation between Heredity and Environment
u = $r_{Q_0 Q_2} = \frac{g^2}{4}d + e^2 r_{E_0 E_2} + 2egr_{Q_0 E_2}$
w = $r_{Q_0 Q_3} = \frac{g^2}{4}(1+2m+d) + e^2 r_{E_0 E_3} + 2egr_{Q_0 E_3}$
v = $r_{Q_0 Q_1} = \frac{g^2}{2}(d+m) + e^2 r_{E_0 E_1} + egr_{E_0 Q_0} + egr_{Q_0 E_0}$
r = $r_{Q_0 Q_1} = \frac{g^2}{2}(1+m) + e^2 r_{E_0 E_1} + egr_{E_0 Q_0} + egr_{Q_0 E_0}$
r - v = $\frac{g^2}{2}(1-d)$ (if all daughters were tested in one herd)
w - u = $\frac{g^2}{4}(1+2m-3d) + e^2(r_{E_0 E_3} - r_{E_0 E_2})$

FIG. 3. Path coefficient diagram showing the causes of the correlations between the records of daughters and of dams.

yields estimate of heritability of intra-breed differences between cows. A small amount should then be deducted from that to allow for the (comparatively few) cases in which a sire was proved in two or more herds differing (of course) somewhat in management. The estimate of milk in the Ayrshire breed is certainly too low because of the time trend which contributed considerably more to u, w, and v than it did to r,[3] as was mentioned above. The

[3] The figure for r came wholly from Rice's table 1 which covered only a short period of time. The figures for u, w, and v came from differences or ratios between statistics in his table 1 and in his table 4, the latter having extended over a considerably longer period.

three other estimates are compatible with most of those derived from other studies, namely something under 0.3 (perhaps under 0.2) for differences in milk records and something of the order of 0.5 to 0.7 (or less if the data included many sires which each had daughters in more than one herd) for differences in test. A strong influence of contemporaneity on Ayrshire milk and Holstein test may be indicated by w being so distinctly larger than u, but perhaps that needs confirmation on more extensive data before effort is spent on finding an explanation for it. Certainly the daughters' records would generally have been made within a more restricted range of time than the records of the dams.

The similarity of r_{XY} in the data for Herd Improvement Registry (Rice's table 4) and in the Dairy Bureau data for Dairy Herd Improvement Associations (Rice's tables 2 and 3) tempts one to suppose that heritability and the other factors affecting sire proving are the same in both kinds of data. However, the numerical value of r_{XY} depends more on the ratio of v to u and w than it does on the difference between r and v. The topic merits further study.

OPTIMUM VARIABILITY FOR SIRE INDEXES

The variability of a sire index does not alter its *accuracy* (provided there are at least 16 to 20 classes from the lowest to the highest figure) but may affect considerably its convenience in use and its susceptibility to misinterpretation. The variability of the index can be made as large or as small as one chooses by altering the value of c. Two plausible definitions for the variability which a sire index should have for maximum convenience in actual use are as follows: A. The index should equal the most probable breeding value of the sire. B. The index should have the same standard deviation as the records of cows.

The theoretical advantages of standard A are obvious. It expresses the sire proof directly in terms of the goal for which indexes (and indeed all forms of progeny testing or estimating breeding value) are intended. Under it the c of equation (1) should make $\sigma_I = r_{GI}\sigma_G$. To do this requires that c be approximately $\frac{g^2}{2} \cdot \frac{\sigma_O^2}{\sigma_X^2} \cdot \frac{1}{1 - r^2_{XY}}$ which in the data pertaining to dairy sires comes close to $2g^2$. For example, it has values of 1.65, 1.82, 2.10, and 1.84 g^2 in Rice's table 6 for Ayrshire milk and test and Holstein milk and test, respectively. Unfortunately the value of g^2 is not known with high certainty (*i.e.*, within really narrow fiducial limits) in any population. In most dairy data it seems to be around 0.15 to 0.30 for quantity of milk and somewhat higher—perhaps above 0.50—for test. Moreover g^2 will vary a bit as there is more or less care in controlling or correcting for environmental variables, a larger or smaller number of daughters, whether single records or lifetime averages are used for daughters and for dams, etc.

Attempting to state the proper numerical value for c turns the spotlight

on the practical difficulty of using standard A, namely the uncertainty about the precise value of g^2 to use, the variation (usually slight) in that from one population to another, and the large variation in g^2 from one characteristic to another, with the resultant necessity of using one formula for test, another for milk, etc. Also many will think "most probable breeding value" is more theoretical and intangible than an actual record (D or O) which is a familiar and very real thing to them. If standard A is used, the index of a sire cannot be compared directly with the record of a cow until the cow's record is first translated to the scale of "probable breeding values" by regressing it $1 - g^2$ of the way toward the breed average.

Any change from one standard to another will always cause considerable confusion. It would be unfortunate to adopt standard A now and start indexing sires, using 0.40 as c for milk and 0.80 as c for test, only to find three or four years later that 0.50 and 1.10 or 0.30 and 0.70 would have been more accurate for most dairy populations. Eventually we may come to standard A or something very similar, but the change should first receive considerable scrutiny and much trial and actual practice.

Standard A automatically discounts the records for the average amount of non-genetic variation in them and thus protects the user against too easily falling a victim to his wishful thinking. No index can be guaranteed to show the breeding values of each individual proven sire correctly but a scale which is just as likely to rate an individual too low as too high is less susceptible to misinterpretation than one on which the high indexes are generally higher and the low indexes are generally lower than the breeding values of the sires to which they apply.

Standard B puts the indexes of sires and the records of dams on an equal footing, so that they can be compared directly.[4] For σ_I to equal σ_D exactly

[4] Strictly speaking, this requires that mean I and mean D be approximately equal (since in most dairy data X differs little from Y) and that $\frac{\sigma_I}{r_{IG}} = \frac{\sigma_D}{r_{DGd}}$ where Gd is the breeding value of the cow who has record D. The writer has shown (JOUR. DAIRY SCI., 18: 1–19. 1935) that r_{IG} and r_{IGd} will not be far apart if heritability is larger than 0.10 and especially if (as seems almost always to be the case in dairy data collected from several herds) the environmental contribution to the correlation between daughters of a sire is +0.10 or larger. The argument may be reviewed here in slightly different terms by referring to the composition of r_{IG} as shown in figure 1. When r_{GY} = zero and $r_{XY} = 0.5$, r_{IG} reduces to $r_{GO}\sqrt{\frac{n}{1+(n-1)u}}\sqrt{\frac{4}{3}}$. Now r_{GO} is half the correlation between a daughter's record and her own breeding value. This latter correlation will be the same as between a dam's record and her breeding value (r_{DGd}), except as more intense selection among the dams than among the daughters may have reduced r_{DGd} slightly and more lactations per dam than per daughter may have raised r_{DGd}. Hence $\frac{r_{IG}}{r_{DGd}}$ is approximately $\frac{\sigma_O}{\sigma_X} \cdot \frac{1}{\sqrt{3}}$ which isn't very far from unity. It has values ranging from 0.86 to 0.99 in Rice's table 6 but perhaps should be increased a little to allow for the dams having been a bit more highly selected than the daughters were. In short, selection of dams on their own records will rarely be either much less or much more accurate than selection of sires on their indexes.

requires that $c = \frac{\sigma_D}{\sqrt{\sigma_X^2 + b^2\sigma_Y^2 - 2br_{XY}\sigma_X\sigma_Y}}$. If r_{GY} is zero and $r_{XY} = 0.5$, this is $\sqrt{\frac{4}{3}}\sqrt{\frac{n}{1+(n-1)w}}$ which, for most of the likely values of n and w, gives c a value not far from 2.0—more often a little less than a little more. Rice's table 6 would require for c values of 1.74, 1.71, 2.03, and 1.85, respectively, to make the index conform exactly to standard B. The EP index, now rather widely used, has 2.0 for c and therefore comes fairly close to standard B. The EP index cannot be equalled for simplicity of computation, among indexes which use an approximately correct value for b.

If the index is used only for comparing the sires with each other and with cows, no further step than standard B is necessary. For reducing indexes (or records of cows) to breeding values or for predicting the production of future offspring the indexes (or records) need to be regressed toward the average of the breed far enough ($1 - g^2$ of the way) to allow for the average amount of non-genetic variance in them. If this second step is neglected or not understood, the user of indexes constructed according to standard B (or the user of cows' records) may easily build hopes too high (in terms of actual pounds or per cent) on the bulls or cows with the high figures and may damn more severely than he should those with low figures.

In principle standards A and B differ only in that the regression toward the breed average is "built into" the operation of figuring the index under A and hence is already accomplished when the index is obtained, while B requires two steps to reach the same goal. The first step yields the index itself, which can be compared directly with the records of cows but is more variable than breeding values. The second step (which is not necessary for comparing sires with each other or with cows and hence is often omitted) is to estimate probable breeding value from the index by regressing it $1 - g^2$ of the way toward the breed average.

Rice's NEW index, which uses 1.0 for c, comes near to standard A for test but the proper value for c for quantity of milk is not that large. The breeding values of sires for amount of milk or of fat will generally be nearer to the breed average than their NEW indexes. The NEW indexes are simply EP indexes regressed half way toward the breed average—*i.e.*, the NEW index for each bull is exactly half way between his EP index and whatever constant figure is used for the breed average in computing the NEW index. Since this difference is only one of coding (*i.e.*, the EP index is divided by two and then has a constant added to it to form the NEW index), the two indexes have the same correlation with any other variable and are equally accurate for comparing one sire with another.

PREDICTING THE ACTUAL PRODUCTION OF FUTURE DAUGHTERS

For predicting the production of a future daughter the correct procedure in principle is simply to average the most probable breeding values of the dam

and the sire. Then this average should be raised or lowered enough to allow for the environment in which the daughter is to make her record being better or worse than average. But in practice we rarely have any direct measure of that environment. Probably the average record of that herd for the most recent two or three years could be used advantageously for this purpose, but this is not yet being done generally. The environment pertaining to the daughter will usually be correlated slightly (something of the order of +0.2 to +0.3) with the record of her dam if she and her dam make their records in the same herd. It will usually be still more closely correlated (something of the order of +0.4 to +0.6) with the index of her sire if she is to make her record in the same herd as the one in which her older sisters made the records on which that index is based. In this latter case the sire index assumes a large part of the predictive value which would attach to the direct measure of the daughter's herd environment if such a measure were available. Because of its lower correlation with the herd environment, the dam's record does not assume much of this predictive value for environment if the sire index was made in the same herd but it does assume considerable if the daughter is to make her record in the same herd as her dam but in a different herd from that in which her sire was proved. If the daughter is to make her record in a herd in which neither her dam nor her sire's earlier daughters were tested (an uncommon case in dairy data), then both the sire's index and the dam's records are useful only for their genetic relation and neither of them will help as an indicator of the herd environment under which the daughter will make her record.

If sire indexes are to be used almost solely for estimating the production of future daughters, either singly or in groups, then one can make a good case for building into the index enough extra variation to allow also for its importance as an indicator of non-genetic circumstances (*i.e.*, for the kind of environment) which will prevail for that daughter or those daughters. But D also should receive extra weight for its real, although generally lesser, usefulness for the same thing. This leads at once to four different scales for σ_I and σ_D (or four different factors by which to multiply them), according to whether the future daughter is to make her record in the same herd as her dam and her older paternal sisters, in the same herd as her dam but a different one from her sisters, in a different herd from her dam but the same herd as her sisters, or in a different herd from either her dam or her sisters. Possibly there is some simple way of doing that but it seems to the writer probable that the simplest way will be to use standard A (which is standard B regressed $1-g^2$ of the way toward the breed average) and then modify the prediction up or down according to whether the most recent average of the herd in which the daughters are to be tested is above or below the breed average.

Predictions of the production of an individual future daughter cannot be expected to be highly accurate. A correlation of around 0.1 to 0.2—*i.e.*,

g^2 times the square root of one-half—between the actual and the predicted record of the individual daughter (for quantity of fat or milk—a bit higher for test) is about as much as can reasonably be expected if the dam has only one lactation and the sire's proof was of only average accuracy and the daughter is to make her record in a different herd. Although this would be raised distinctly if the dam is judged by all of her records and if there were three or more of those, and if the sire's proof is unusually accurate by reason of a large number of daughters and unusually careful discounting of the environmental circumstances which applied to his daughters and mates, yet it seems unduly optimistic to expect by that means to attain an average accuracy as high as a correlation of +0.4 between actual record and predicted record.

The average production of n future daughters can of course be predicted more accurately than the production of one daughter. This is only an automatic result of the averaging process and does not introduce any new biological principle. The averaging permits many of the chance circumstances, which cause a daughter to produce more or less than was predicted, to cancel each other's effects in the average of n daughters. The correlation between prediction and fact is $\sqrt{\frac{n}{1+(n-1)w}}$ times as large when predicting the average production of n daughters as when predicting the production of one daughter. Also σ_X is only $\sqrt{\frac{1+(n-1)w}{n}}$ as large as σ_O and this of itself makes the error of prediction seem smaller, if that error is measured in actual pounds or percent instead of being measured relative to σ_X or σ_O. The net result is that in actual units the standard error of estimating the average of n daughters is only $\sqrt{\frac{1-w+n(w-t^2)}{n(1-t^2)}}$ as large as the standard error of estimating one daughter, where t is the correlation between prediction and fact when predicting one daughter.

SUMMARY

Nearly all sire indexes which have been proposed can be described by the general equation, $I = a + c(X - bY)$, in which a, b, and c are constants, X is the average production of the daughters, Y is the average production of their dams and I is the index.

The size of a affects only the general level (the mean) of the indexes. The size of c affects the variability of I but not its accuracy for comparing the breeding values (G) of two or more indexed sires. The size of b affects the acuracy of the index as well as its variability.

The main contribution of this paper is in showing that maximum accuracy of the index is attained when $b = \frac{\sigma_X}{\sigma_Y} \cdot \frac{r_{GX}r_{XY} - r_{GY}}{r_{GX} - r_{GY}r_{XY}}$. If r_{GY} = zero this

optimum value of b becomes simply the regression of X on Y. If r_{GY} has a small positive value (as is possible if breeders whose cows have high records generally try harder than other breeders to get good bulls—and if the extra efforts are partially successful) the optimum value of b is a little less than the regression of X on Y. The regression of X on Y is about 0.5 to 0.6 both for milk and for test in most sets of data actually used for proving dairy sires. The optimum value for b in dairy data will, therefore, be not far from 0.5.

If r_{GY} is zero, selection of sires on the optimum index, as thus defined, will make $\frac{1}{\sqrt{1-r^2_{XY}}}$ times as much progress as choosing the sires on the average of their daughters alone. The size of this factor, when r_{GY} is very small and r_{XY} has such values as are usually encountered in proving dairy sires, is about 1.12 to 1.20.

The size of r_{XY} or of the regression of X on Y is affected more by the correlation (v) between a daughter's record and the record of a mate of her sire, other than her own dam, than it is by the correlation (r) between a daughter and her own dam, especially when n is large. The regression of X on Y approaches $\frac{v}{u}$ and r_{XY} approaches $\frac{v}{\sqrt{uw}}$ as a limit when n becomes extremely large, u being the phenotypic correlation between the mates of the same sire and w being the phenotypic correlation between daughters of a sire.

A sire index can be made as variable as desired by adjusting c. The value 2.0, used for c in the intermediate or equal-parent indexes makes σ_I generally just a little larger than σ_D or σ_O. This index can be used rather fairly for comparing proven sires directly with individual cows, as is necessary in evaluating pedigrees. It is, however, more variable than real breeding values. Consequently, if it is to be used directly as the sire's most probable breeding value, the index needs first to be regressed far toward the breed average (just as cows' records do) to allow for the average amount of non-genetic variation in such indexes. Approximately this amount of regression would already be accomplished in an index which used for c twice the heritability of differences between the records of individual cows. Rice's proposed "NEW" index, which uses 1.0 for c, is the equal-parent index regressed half way toward the breed average. It is, therefore, half as variable but has exactly the same accuracy.

THE RELATIVE CONCENTRATIONS OF DAM AND FETAL LIVER GLYCOGEN*

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The composition of the blood of calves immediately following birth differs in certain respects from that of their dams. It was reported by Knodt, Shaw, and White (3) that the blood acetone bodies of calves at birth are significantly lower than that of their dams. Bodden and Allcroft (1) presented data demonstrating higher levels of blood sugar, serum calcium, inorganic phosphorus, and non-protein nitrogen but a lower level of chlorine in the blood of calves as compared to their dams at the time of parturition. Because of the relationship which apparently exists between the calves and their dams relative to the concentrations of blood glucose and acetone bodies, it was decided to determine the levels of liver glycogen of feti and their dams and compare these observations with those previously made.

EXPERIMENTAL

Previous work has shown that the level of blood glucose of calves at birth is higher than that of their dams. It would appear that a somewhat similar relationship might exist with regard to the concentrations of liver glycogen. A high level of liver glycogen in calves should be important in the maintenance of a higher concentration of blood glucose and a lower level of blood acetone bodies in calves following birth as compared to their dams. It is obvious that data relative to the concentrations of liver glycogen are difficult to obtain and involve the destruction of the animals. The animals used in this work were those passing through a local abattoir.

The age of the feti was estimated as 8 to 9 months. The cows were killed in the usual manner and the samples of the left lobe of the dam and fetal livers were removed immediately for glycogen analyses. The tissue samples were placed in warm, previously weighed 50 per cent potassium hydroxide and the glycogen analyses were made by the method of Good, Kramer, and Somogyi (2). Data are presented in table 1 on 20 cows and their feti. The average concentration of fetal liver glycogen was 4.12 per cent whereas that of the dams averaged 0.25 per cent. In no case was the level of fetal liver glycogen lower than that of the dam. The level of fetal liver glycogen varied from 2.67 per cent to 5.36 per cent while that of the dams varied only from 0.15 per cent to 0.38 per cent.

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The low level of glycogen in the dams' livers was probably due in part to the effect of inanition since these cows had probably not been fed for at least 24 hours previous to slaughter. It is significant that the feti were able to maintain a comparatively high level of liver glycogen in spite of the extremely low level of liver glycogen of their dams.

A somewhat similar relation may exist in normal cows where these levels may not differ so markedly. When these observations are related to the comparative levels of blood acetone bodies of calves and their dams at the time of parturition (3) it will be observed that there is an inverse relation-

TABLE 1

Concentration of glycogen in dam and fetal livers

Expt. No.	Concentration of liver glycogen (%)	
	Fetus	Dam
1	4.50	0.20
2	3.85	0.24
3	3.29	0.22
4	5.41	0.27
5	3.48	0.21
6	3.88	0.26
7	5.06	0.35
8	4.23	0.17
9	2.96	0.28
10	3.52	0.26
11	4.22	0.38
12	4.76	0.31
13	5.02	0.18
14	4.90	0.27
15	5.36	0.23
16	4.16	0.23
17	4.40	0.34
18	3.86	0.18
19	2.67	0.26
20	2.93	0.15
Average	4.02	0.25

ship between the levels of liver glycogen and the level of blood acetone bodies. It has been observed that the level of acetone bodies is higher in the dam than in the calf at the time of parturition. It has been shown that the feti maintain a higher liver glycogen under the conditions of the experiments. This is in direct agreement with the observations of Bodden and Allcroft (1) demonstrating the higher blood glucose level of calves as compared to their dams.

Observations have been presented by Roderick, Harshfield, and Hawn (4) in which it was shown that the liver of a new-born lamb possesses a glycogen reserve of 2 to 3 times that of the liver of the ewe. They performed biopsies and removed portions of the livers of ewes and lambs which showed evidence of ketosis of starvation and showed that abnormal deposition of fat had occurred in these livers. Evidence was also presented to show that

upon feeding these animals until they had returned to normal the fat had been gradually removed from the liver and glycogen had been stored.

Samples were taken from the livers of 15 calves from 3 to 6 weeks of age. The age was again estimated. The samples were taken from the left lobe of the livers immediately after the calves were killed but showed considerable variation in the concentration of liver glycogen. The average of these samples was 2.60 per cent with a range from 0.24 per cent to 7.81 per cent glycogen.

It appears that the levels of various compounds such as liver glycogen, blood glucose and acetone bodies, serum calcium, inorganic phosphorus, non-protein nitrogen, and chlorine are maintained at levels in the feti which are to a certain extent independent of the levels concurrently present in the dam.

CONCLUSIONS

1. The fetus is able to maintain a much higher level of liver glycogen than that of its dam under the particular conditions encountered in these experiments.

2. There appears to be an inverse relationship between the concentrations of liver glycogen and blood glucose as compared with acetone bodies between the fetus and its dam at the time of and prior to parturition.

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THE STIMULATION AND INHIBITION OF MILK SECRETION IN GOATS WITH DIETHYLSTILBESTROL[1, 2]

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Research work of the past few years has suggested the rather anomalous fact that the administration of estrogens (and diethylstilbestrol) in certain amounts may be effective in stimulating the initiation of milk secretion in virgin or parous non-lactating animals while at the same time established lactation may be seriously depressed by these same hormones. Folley *et al.* (4, 5, 6), Lewis and Turner (8, 9, 10, 11), Walker and Stanley (25), and Reece (20, 21) have adequately demonstrated that diethylstilbestrol, a synthetic estrogen, will initiate lactation in dairy goats and cattle. Many investigators (see Meites and Turner (14) for review) using the smaller experimental animals have claimed that estrogen can diminish or completely suppress lactation and, in fact, was the mechanism by which lactation was held in check during pregnancy (24). In goats de Fremery (7) reported depression of lactation with estrogen and in cattle Folley (2) and Walker and Stanley (25) observed similar effects. These latter workers suggested that large amounts of estrogen inhibit while smaller amounts stimulate milk secretion.

If lactation is inhibited by large amounts of estrogen (or diethylstilbestrol) the mechanism of this inhibition should be sought since Meites and Turner (14) showed that diethylstilbestrol even in relatively huge doses increased the lactogenic hormone content of the pituitary of rats and guinea pigs. Further, if the use of diethylstilbestrol is to become a practical procedure for the initiation of lactation in sterile animals, the dosages which will stimulate lactation in various species must be clearly differentiated from those which will suppress lactation.

PROCEDURE

The goats used in these experiments were grade Toggenburgs. They were fed a mixed grain ration and either lespedeza or alfalfa hay and were milked twice daily. During the experimental periods diethylstilbestrol dissolved in olive oil was injected subcutaneously once daily or was administered orally by capsule.

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EXPERIMENTAL RESULTS

Initiation of lactation. The first section of this paper is concerned with the initiation of lactation in five virgin yearling goats by the injection of 0.25 mg. per day of diethylstilbestrol, a dosage which was found by Lewis and Turner (11) to be optimal for this purpose in goats. Injections in these goats (Nos. 258, 351, 176, 355 and 569) were started on September 8, 1942, and were continued until January 9, 1943. Injections were reinitiated on February 8, 1943, and were continued for nearly another month at which time the experiment was terminated by taking a mammary gland from each animal for histological study. Milking of these animals was started on December 9, 1942, and was continued through the balance of the experiment.

FIG. 1. The milk production records of five virgin female goats in which lactation was induced by the daily subcutaneous injection of 0.25 mg. of diethylstilbestrol. Injections were started on September 8, 1942, and were continued through January 9, 1943, were reinitiated on February 8, 1943, and were continued through the balance of the experiment.

As may be seen in figure 1, there was a great variation in the amount of milk given daily by the individual goats under identical treatment. It is interesting to note that there was no special reaction in milk yield when the diethylstilbestrol was discontinued on January 9, 1943. However, when the administration of diethylstilbestrol was reinitiated on February 8, 1943, there was an immediate drop in milk production in all goats. This drop was quickly recovered and in two instances (Goats 351 and 176) the milk production which followed was considerably higher than that previously attained. It will be noted in the case of Goat 569 that milk secretion was not initiated at all until after the start of the second period of diethylstilbestrol administration.

A report on the state of mammary gland growth in these animals at the end of the experiment (February 24, 1943, for Goats 258 and 569, and March 3, 1943, for Goats 351, 176 and 355) has already been made (18). This study of the mammary glands indicated that milk production was roughly proportional to the amount of mammary gland growth secured. The highest producing goat (No. 258) had a rather extensive development of the lobule-alveolar or milk secreting system, while the low producing goat (No. 569) showed only a hypertrophy of the duct system with limited milk secretion. It would seem, then, that individual goats vary widely in their lactation response to diethylstilbestrol, primarily because of the great difference in mammary growth elicited by the standard dosage of diethylstilbestrol. Of course, it is also possible that the lactogenic hormone of the anterior pituitary was not stimulated to the same degree in the various animals by the diethylstilbestrol.

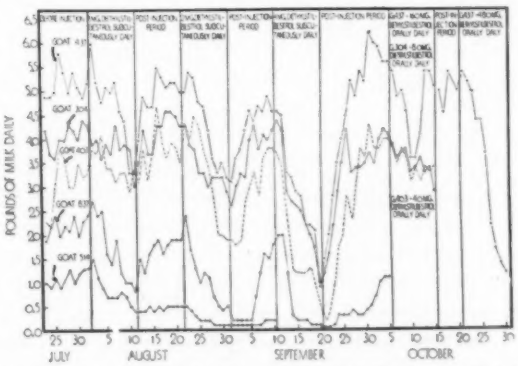

FIG. 2. A record of milk production and diethylstilbestrol administration in five parous goats. Note the depression in milk production coincident with the injection of 1.0 mg., 2.0 mg. and 4.0 mg. of diethylstilbestrol daily for ten-day periods, respectively. Also note the depression in milk production starting October 6, following the oral administration of diethylstilbestrol.

Inhibition of lactation. The second section of this paper is concerned primarily with the effect of varying dosages of diethylstilbestrol on established lactation in parous goats. The usual procedure was to inject the diethylstilbestrol daily over a ten-day period and then allow a ten-day post-injection period. By the trend of milk production over these periods the effect of the diethylstilbestrol injections could be determined.

In preliminary trials three goats were used to determine the effect of daily injections of 0.1 mg. and 0.2 mg. of diethylstilbestrol on milk production. No effects on milk production ascribable to the diethylstilbestrol could be detected. In two other goats the effects of 1.0 mg., 2.0 mg., and 4.0 mg. of diethylstilbestrol daily on milk production was studied. The indi-

cations from these two goats were that 1.0 mg. of diethylstilbestrol daily inhibited milk production slightly while 2.0 and 4.0 mg. dosages of diethylstilbestrol daily were very definitely inhibitory in nature. However, these goats were in an advanced stage of lactation and the results may have been influenced to some degree by this fact.

Therefore, in later trials five goats were used in similar studies. Three of these goats (Nos. 437, 304 and 403) were in early stages of lacation while the two other goats (Nos. 837 and 514) were in more advanced stages. Ten-day periods of diethylstilbestrol injections were followed by ten-day periods in which no material was injected. The daily dosage of diethylstilbestrol during the first injection period was 1.0 mg., followed in subsequent injection periods by 2.0 and 4.0 mg. daily. The course of these injections and the milk production records of the goats are presented in figure 2. From this figure it will be noted that the lactation is inhibited in all cases by the dosage of diethylstilbestrol injected, the degree of inhibition being proportional to the dosage. Recovery in milk production was effected in all cases in which the original level of milk production was relatively high (Goats 437, 304 and 403).

RELATION OF ORAL TO SUBCUTANEOUS ADMINISTRATION OF DIETHYLSTILBESTROL

The oral administration of diethylstilbestrol in small experimental animals and in man has been quite effective in comparison with subcutaneous administration. In ruminants, however, there appears to be large losses in the digestive tract. Folley *et al.* (4) gave 1 gm. as a drench to a cow without effect on lactation. Lewis and Turner (11) observed that 5 mg. per day orally was less effective than 0.25 mg. per day injected subcutaneously in stimulating lactation in goats. Zondek and Sulman (26) have observed that many types of microorganisms inactivate diethylstilbestrol. It appears likely that the microorganisms in the rumen may be responsible for the relative ineffectiveness of this hormone when given orally.

The rather uniform depression of milk secretion in Goats 437, 304 and 403 with increasing dosages of diethylstilbestrol (fig. 2) presents a method for determining the relative activity of diethylstilbestrol administered orally as compared to that subcutaneously administered. Thus on October 6, 1943, oral administration of diethylstilbestrol was initiated, Goat 437 receiving 160 mg. daily, Goat 304 receiving 80 mg. daily and Goat 403 receiving 40 mg. daily for a ten-day period (fig. 2). The lower dosages were rather ineffective or only slightly effective in inhibiting lactation while the highest dosage was slightly effective. In a subsequent period, Goat 437 received 480 mg. of diethylstilbestrol orally daily. The suppression of lactation secured with 480 mg. of diethylstilbestrol orally roughly approximated that secured in the same goat with 4.0 mg. administered subcu-

taneously. These results would indicate then that diethylstilbestrol is roughly 1 per cent as active in inhibiting lactation when administered orally to goats as compared to subcutaneous administration. Presumably, this same relationship would be true for lactation-stimulating dosages. Thus if 0.25 mg. of diethylstilbestrol subcutaneously is effective in stimulating lactation, 25 mg. would be required to be equally effective orally.

DISCUSSION

The experiments with goats reported in this paper serve to distinguish between a lactation-stimulating dosage and a lactation-inhibiting dosage of diethylstilbestrol. The variability in the response of goats on the lactation-stimulating (0.25 mg) level raises the question whether a slightly higher dosage might have stimulated greater mammary gland growth and lactation. It is also possible that 0.5 to 1.0 mg. per day might stimulate more extensive growth of the gland even at the expense of lactation and that upon the reduction of the level to 0.25 mg., the lactation-stimulating response would predominate.

The data presented confirm and extend the earlier observations of Folley (2, 3) Walker and Stanley (25) and Lewis and Turner (11) that certain levels of diethylstilbestrol will depress established lactation. The present observations indicate that the inhibition is temporary and lactation may actually return to as high or higher level following the period of administration, at least in early stages of lactation.

The large oral requirement of diethylstilbestrol in comparison to the subcutaneous dosage points to huge losses in the rumen or other parts of the digestive tract. This is unfortunate as diethylstilbestrol might otherwise be added to the grain mixture of sterile animals to initiate the lactation process.

Meites and Turner (14, 15, 16, 17) suggested that lactation is initiated at about the time of parturition by the presence of increased amounts of physiologically active estrogen acting upon the pituitary and stimulating the secretion of increased amounts of the lactogenic hormone. The action of the lactation-stimulating dosage of diethylstilbestrol would fit in with this theory. The fact that large amounts of diethylstilbestrol do not inhibit the secretion of the lactogenic hormone necessitates another explanation for the lactation-inhibiting action of this compound.

It has been suggested that estrogen may inhibit milk secretion by acting directly upon the secreting cells of the mammary gland (Nelson, 19). There are several reasons to believe that the action of estrogen in producing an increased hyperemia and permeability of the vascular system of the mammary gland would be favorable to the transfer of milk precursors to the secreting epithelium (Mixner and Turner, 18).

During the past few years, it has been demonstrated that diethylstilbestrol causes enlargement of the adrenal cortex (see 1, 12, 22, 23 for

review). This effect is produced through the mediation of the pituitary and, presumably, by the stimulation of increased secretion of the adrenocorticotrophic hormone. Certain hormones secreted by the adrenal cortex are known to increase the rate of deaminization of the amino acids (protein catabolism) with the production of glucose (12). If the process of deaminization were to be carried on too actively, the nitrogenous precursors of milk protein would become limited and the milk secretion process might be expected to be inhibited.

It is significant that diethylstilbestrol (22, 23), adrenocorticotrophic hormone (13) and certain adrenal cortical hormones have depressing effects upon the growth process also. It is believed that both milk secretion and the growth process are depressed by the same chain of events stemming from the action of diethylstilbestrol upon the pituitary and the adrenal. Other factors which are known to cause adrenal hypertrophy would be expected similarly to depress milk secretion (23).

The adrenal hypertrophy observed in some species during late pregnancy and the return to normal size during early lactation may explain the mechanism of control of the rising segment of the lactation curve. Pathological conditions at the time of parturition, such as retained placenta, which would maintain adrenal hypertrophy would inhibit milk secretion so long as the condition persisted.

SUMMARY

The relation between lactation-stimulating and lactation-inhibiting dosages of diethylstilbestrol in dairy goats was established in these experiments. A daily dose of 0.25 mg. of diethylstilbestrol constitutes a lactation-stimulating dosage in nonparous goats while dosages varying from 1 to 4 mg. per day were progressively lactation-inhibiting in lactating goats.

As judged by the lactation-inhibiting effect, diethylstilbestrol orally administered is only about 1 per cent as effective as when administered subcutaneously.

The lactation-stimulating effects of small dosages of diethylstilbestrol are due to its ability to stimulate the secretion of the lactogenic hormone by the anterior pituitary gland while the lactation-inhibiting effects are believed to be correlated with increased adrenal-cortical activity resulting in an increased rate of deaminization of the nitrogenous precursors of milk protein. It is suggested that the hormones of the adrenal cortex play a role in regulating the course of the rising segment of the lactation curve.

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THE CONTROL OF DIARRHEA ("WHITE SCOURS") OF NEW-BORN DAIRY CALVES BY MEANS OF SERUM AND SULFAGUANIDINE*

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Wherever cattle raising is an intensive industry, diseases of various types frequently occur in new-born calves, losses of which sometime reach appalling magnitudes in individual herds. The most prevalent cause of these losses (13, 15, 16, 17) is "white scours."

The control of this disease is of great economic importance to the dairymen in their expansion program and of interest to the nation in its nutritional readjustments. Prior to the rapid advance in chemoprophylaxis and chemotherapy, satisfactory means of coping with this problem were not available. Recent observations on the use of several of the sulfa compounds in the control of calf diarrhea are promising from a practical viewpoint (10, 29, 31, 35, 36, 37).

The primary purpose of this investigation was to obtain additional clinical information on the relative values of a commercial anti-scour serum and one of the sulfonamides, sulfaguanidine (sulfanilylguanidine), as agents for controlling diarrhea of new-born calves under practical herd conditions.

LITERATURE REVIEW

General information on the subject of "white scours" is summarized by Marshall (19), Simms *et al.* (23), Van Es (33) and others. Early experimental investigations pertaining to this and similar diseases of calves have been adequately reviewed and presented by Hagan (8), Hart and Traum (12) and Pfenninger (21).

Nature of "white scours." This disease, also known by various other descriptive terms, is ill defined symptomologically and etiologically. "White scours," according to Williams *et al.* (34), generally refers to an acute diarrhea occurring from a few hours to several days after the birth of the calf. Although scours manifested in an older calf is regarded as a different type and is designated by other terms, the line of demarcation is not clear. Chronological differentiation seems to be adequate to distinguish "white scours" from diarrhea of parasitic origin but not from that of nutritional etiology. Scours due to a deficiency of vitamin A (11) and/or

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to members of the B-complex (22) is occasionally confused with the "white" type. Investigators further agree that this malady frequently coexists with or merges into not only different types of diarrhea but also other diseases, particularly pneumonia, in such a manner that symptomatic delineation is difficult.

Even though past investigations indicate that "white scours" is a diarrhea of bacterial etiology, the possibility that the implicated microorganisms may be secondary invaders cannot be disregarded (2, 9, 14). Organisms of the colon group generally are agreed to be the predominating type present, but no investigator holds that any one organism or variety alone is the all-important etiological factor involved.

The bacterial invasion, according to a summary by Hart and Traum (12), usually takes place post-natally but occasionally *in utero*. The most important channel of infection is the digestive tract, but the umbilical vessels also may be a path of invasion.

Predisposing factors. The predisposing causes of "white scours" are numerous but may be grouped in the following classes: congenital weakness, improper calf husbandry and inadequate nutrition. General recognition of the importance of these first two factors obviates further comment, but recent developments in the nutritional aspects of calf diarrhea warrant consideration in the etiology of "white scours."

The composition and properties of colostrum offer a clue to the physiological needs of the new-born calf. Early investigations by Smith and his associates (24, 25) demonstrated the importance of colostrum in protecting calves against generalized infections by *B. coli*. The protective characteristic has been ascribed to antibodies, but this does not preclude the possibility that the vitamins of the colostrum may play either complementary or supplementary immunological rôles. Latterly, cumulative fragments of evidence tend to support this conjecture.

Investigations by Dann (5) revealed that colostrum is the primary medium through which vitamin A is transmitted to the new-born calf. The immunological importance of the amount of this vitamin in the colostral milk is suggested by the report of Stewart and McCallum (27) showing that calves from dams secreting colostrum having less than 250 blue units per 100 ml. were more susceptible to "white scours" and associated ills than were calves from dams having a greater concentration of vitamin A activity in the colostrum. Recent observations by Moore and Berry (20) indicated further that whenever the colostrum ingested failed to increase the vitamin A and the carotene of the plasma of a new-born calf, it usually died from infection. Either poor quality colostrum or faulty absorption might have been involved in these cases. The relationship of the quantity of vitamin A activity in colostrum to its protective properties needs further investigation.

Phillips and associates (18, 22) emphasized the rôle not only of vitamin A but also that of members of the B-complex and ascorbic acid in the control of calf diarrhea of nutritional origin. However, Thorp (29, 30) was unable to control an acute type of scours, evidently of bacterial etiology, in the day-old calf by the use of vitamins A, B and C as prophylactics.

Sulfaguanidine as a control agent. The general control methods employed in protecting the new-born calf from "white scours" are sanitation, isolation, immunization and chemotherapy. The production of sulfaguanidine has resulted in rapid expansion of chemotherapy in the control of gastro-enteric infections of livestock. Since this compound is readily dissolved in the gastro-intestinal fluid but is not absorbed to any great extent through the intact intestinal mucosa, relatively high concentrations can be maintained in the lumen of the bowel without developing sufficiently high blood and systemic concentrations to produce serious toxic reactions. The bacteriostatic and bactericidal action of this drug on certain organisms markedly alters the flora of the alimentary tract (28), thus rendering the compound effective in the control of various types of calf scours.

The prophylactic dosage of sulfaguanidine for diarrhea of new-born calves has not been established. On the basis of a limited number of observations Wise (35) suggested the following dosage schedule per pound of body weight: first dose, at two to six hours after birth, 0.05 gram; second dose, six hours later, 0.04 gram; and subsequent doses, continued from one to three days of age, 0.025 gram given morning, noon and night. Though this afforded protection, more recent investigations indicate that the quantity prescribed is greater than necessary.

The therapeutic value of sulfaguanidine for "white scours" was indicated in a preliminary report by Wise and Anderson (36). Subsequently Simms and associates (23), from a study of a limited number of cases, stated that this chemical merited further tests. Later reports of extensive and detailed investigations by Thorp *et al.* (29, 31) revealed that sulfaguanidine, properly prescribed, may be used as a curative agent for scours not only of very young calves but also of older ones.

The therapeutic dosage per pound of body weight recommended by various investigators (3, 31, 35, 36) ranges from 0.13 gram to 0.18 gram for the first day, 0.07 gram to 0.17 gram for the second day, 0.07 gram to 0.12 gram for the third day, and 0.06 gram to 0.075 gram subsequently up to six days. Thorp and Shigley (31) prescribed a lower rate for calves weighing less than 75 pounds than for those weighing more, but others (3, 35, 36) suggested the same rate for calves of all sizes. The former also recommended that, throughout, the daily dosages be divided into three equal parts; whereas the latter advocated that the initial doses during the first day be greater than those following, but that the doses for subsequent days be divided into equal parts.

Thorp and Shigley (31) observed that when approximately three times the therapeutic dose was given, toxic symptoms were evidenced in calves. Bankowski and Haring (4) also noted toxic effects when four to five times the therapeutic dose was given. The principal symptoms were "depression, anorexia, hematuria and crystalluria; in the later stages ruffled hair coat, weakness of hind quarters with stiffness in gait. Death from uremic poisoning was preceded by anuria and coma."

The dosage problem is that of producing and maintaining the proper concentration of sulfaguanidine in the digestive tract until the pathogenic organisms are overcome.

EXPERIMENTAL

The experimental observations were made principally in the Clemson College dairy herd following an outbreak of an acute infectious and contagious diarrhea among the new-born calves in 1940. Since then, there has been a recrudescence of the disease in spite of scrupulous sanitation.

FIG. 1. Calf showing two of the characteristic symptoms, sunken eyes and profuse salivation, of "white scours" in the advanced stages.

The experimental subjects for the study of control measures included all the female calves, regardless of congenital weakness, born during the periods of investigation, but only a portion of the males since many of them were removed from the herd within a few hours after they were born.

There was a marked difference in the incidence of the disease among the various breeds (tables 2 and 4) suggesting a greater susceptibility in the Guernseys and the Jerseys than in the Holsteins.

The first symptoms of this malady generally were manifested clinically when the animals were between one and two days of age (table 5). Though the syndrome varied somewhat in individual cases, it was characterized by a variable body temperature, frequently high in the early development and subnormal in the late stages; a loss of appetite; a profuse, fetid, brown to gray serous scours; a rapid dehydration as evidenced by the eyes sinking into their sockets (figure 1) and by an increasing dryness and harshness of the skin; a progessive exhaustion, and a fatal termination within 12 to 24 hours of the onset.

A further indication of the marked dehydration in the scouring calves was hemoconcentration (table 1). Since the loss of 10 per cent of the water of the body causes serious disorders, and the loss of twice this amount causes death (7), it is probable that the severe dehydration is the physiological change primarily responsible for the rapid fatal exhaustion.

TABLE 1

Typical changes in concentration of hemoglobin in blood of new-born calves dying of acute diarrhea

No. of calf	Amount of hemoglobin per 100 cc. blood		Increase in concentration of Hb.
	Within 6 hr. after birth	Within 6 hr. before death	
	gram	*gram*	*per cent*
G–170	11.6	14.4	24.1
A–147	10.7	16.4	53.3
499	10.5	16.1	53.5
Ave.	10.9	15.6	43.1

The autopsy findings also were variable depending on the severity and duration of the disease. Gastro-enteritis was present in all cases, some of which were complicated by septicemic conditions, especially the protracted cases. Hyperemia of the mucosa of the abomasum, of the small intestine and of a short section of the anterior portion of the large intestine was one of the most common abnormalities. Frequently the mucous membrane of the abomasum and the small intestine also was edematous and covered with scattered areas of petechial and confluent hemorrhages. The abomasal contents ranged in volume from one to three or four liters and in consistency from fluid entirely to a combination of fluid and lumps of undigested curd. The size of this coagulated mass apparently was related to the amount of colostral milk consumed during the early stages of the disease. The bowel contents were similar to the excrement in appearance, consistency and odor. Whenever the disease reached the septicemic stage, other organs, particularly the lungs and the heart, were involved.

The bacteria isolated from the organs of four of the calves were primarily of the coliform group, which is the type most frequently found by other investigators.

CONTROL MEASURES

The control measures investigated included in addition to general herd hygienics, the use of vitamins A and D (cod liver oil), a commercial polyvalent anti-scour serum and sulfonamides.

Cod liver oil. In view of the fact that vitamin A deficiency is considered a factor predisposing calves to diarrhea, a preliminary approach to the problem was made by giving cod liver oil (Nopco XX)[2] in doses of 20 to 25 cc. as a prophylactic agent, morning and night. This treatment was initiated when the calf was six to 12 hours of age and continued until it either contracted scours, in which case the dosage was doubled as a therapeutic, or until the calf was three days of age. Since cod liver oil was relatively ineffective in the limited number of cases observed, this treatment was discontinued.

These results indicate that excessive amounts of vitamin A do not augment perceptibly the prophylactic value of colostrum from cows maintained under good herd management. In cases of deficiencies it is probable that vitamin supplements would be beneficial.

Antibacterial serum. Though reported results from the use of calf-scours serum on the market have been inconsistent (12), the successes were considered sufficient to warrant further investigation. A commercial polyvalent antibacterial serum (Anti-Coli-Enteritidis-Pasteurella Serum[3]) was used prophylactically and therapeutically in doses ranging from the prescribed amount (10 to 20 cc. for prevention and double this amount for treatment) up to five times these quantities in efforts to control the diarrhea. The initial prophylactic dose usually was given subcutaneously within 30 minutes after the birth of the calf, but in several cases six hours elapsed before the injection.

The results of observations on the prophylactic efficiency of the serum during a 30-month period following the outbreak of the diarrhea are presented in table 2. It is obvious from this summary that the serum did not reduce the incidence of scours in the calves. Yet, it would be fallacious to assume that the serum was deleterious as the data indicate, since it was used only when the incidence was high. The failure of the serum to immunize the calves against the causal agents may be attributed to its impotency and/or non-specificity. It is probable that the preparation and use of an homologous hyperimmune serum would have been a more effective prophylactic (6) than the commercial preparation.

The twofold use of the serum as a prophylactic at birth and as a therapeutic when the first symptoms of diarrhea were noted saved seven, 63.6 per cent, of 11 calves; whereas none of 20 untreated cases, irrespective of the use of the serum as a prophylactic alone, survived. The cost, however, of re-

[2] National Oil Products Co., Harrison, N. J.

[3] Jen-Sal Laboratories, Inc., Kansas City, Mo.

TABLE 2

Prophylactic value of commercial polyvalent antibacterial serum in the control of acute diarrhea in new-born female dairy calves

Breed	Antibacterial serum		No prophylactic	
	Number of calves	Contracted scours	Number of calves	Contracted scours
		per cent		*per cent*
Holstein	51	7.8	28	10.7
Guernsey	32	34.4	18	27.8
Jersey	44	40.9	33	15.2
Cross	5	60.0	6	0.0
All breeds	132	27.3	85	15.3

peated injections of large doses of the serum as a therapeutic rendered this measure prohibitive for practical dairy herd management.

Sulfaguanidine (sulfanilylguanidine).[4] This compound was used both as a prophylactic and a therapeutic agent. In all cases the doses were given in an aqueous suspension as a drench.

a. *Prophylaxis.* Since the most susceptible period in the life of the calf is from birth to 48 hours, it was necessary to employ preventive agents only for this period. The dosage schedules shown in table 3 were effective in reducing the incidence in three herds where scours was prevalent among the new-born calves. In herd A, composed of Jerseys, Guernseys and Holsteins, two-gram doses were given throughout regardless of breed, size and age of calf. In herds B and C the size of the dose was decreased with age since the resistance of calves is known to increase rapidly from birth to two days.

Listlessness and anorexia were noted occasionally in calves following the initial dose. One observer[5] found that this could be averted by withholding the sulfaguanidine until the calf had nursed.

This observation suggests that colostrum affects the absorption of sulfaguanidine. The relationships of the age of the calf and the kind and the

TABLE 3

Dosage schedules for sulfaguanidine given as a prophylactic for scours of new-born calves in different herds

Dose	Age of calf	Amount of sulfaguanidine per cwt. of calf		
		Herd A (Mixed)	Herd B (Holstein)	Herd C* (Guernsey)
	hours	*grams*	*grams*	*grams*
1	2–6	2.2–3.6	2.1	3.7
2	8–12	2.2–3.6	1.6	2.9
3	20–24	2.2–3.6	1.0	2.2
4	32–36	2.2–3.6	.....	.....

* Dosage rate calculated from standard weight of calves for breed.

[4] Supplied by Lederle Laboratories, Inc., New York, N. Y.

[5] E. T. McClure, Dairyman, South Carolina State Hospital Dairies, Columbia, S. C

amount of feed consumed to the absorption of this chemical and its consequent toxicity and effectiveness remain to be determined. Thorp (29) stated that in the practical use of sulfonamides cognizance should be taken of the fact that they are more toxic for younger calves than for older ones. Since the permeability of the intestinal tract to and the selective absorption of certain colostral constituents are known to be markedly reduced during the first day after birth, it is possible that age and/or colostrum affect the permeability of the intestinal mucosa to the sulfonamides. Further information on this point is needed to establish the optimum prophylactic dosage schedule for sulfaguanidine.

b. *Therapeusis.* The therapeutic effectiveness of sulfaguanidine for scours in new-born calves is indicated in tables 4 and 5. The incidence

TABLE 4

Comparative incidence of scours in new-born female calves and the resulting mortality rate during two consecutive periods: (I) without sulfaguanidine therapy and (II) with sulfaguanidine therapy

Breed	15-month periods	Total No. of calves	Calves contracting scours	
			Total	Mortality rate
			per cent	*per cent*
Holstein	I	36	2.8	0.0
	II	43	13.9	0.0
Guernsey	I	27	37.0	70.0
	II	23	26.1	16.7
Jersey	I	46	32.6	73.3
	II	31	29.0	11.1
Cross	I	5	40.0	100.0
	II	6	16.7	0.0
All breeds	I	114	23.7	74.1
	II	103	21.4	9.1

(table 4) was essentially the same for the comparative periods, before sulfaguanidine therapy was initiated and after, but the mortality rates were strikingly lower in the latter period. The 25.9 per cent survival in period I resulted from the use of the aforementioned combined serum prophylaxis and therapeusis.

Of the 56 cases treated with sulfaguanidine (table 5) 26 were females and 30 were males in which groups the respective mortality rates were 7.69 per cent and 20.0 per cent. The higher fatality in the males is attributable primarily to the extreme stages to which the disease was permitted to advance in order to ascertain its critical points. Prognosis was unfavorable, regardless of the quantity and frequency of dosing, after any of the following conditions developed: excessive intestinal hemorrhage, extreme dehydration, and subnormal body temperature.

The total amount of sulfaguanidine given and the number of doses (table 5) varied over a wide range depending upon the severity and the

TABLE 5

Effectiveness of sulfaguanidine as a therapeutic agent for diarrhea of new-born dairy calves

Breed	No. of cases	Ave. age symptoms first noted	Ave. wt.	Sulfaguanidine given		Mortality rate
				Ave. No. doses	Total amt./cwt.	
		hours	*lb.*		*grams*	*per cent*
Holstein	18	31	90	2.0	10.8	22.2
Guernsey	20	43	69	2.0	14.1	10.0
Jersey	17	38	57	2.3	11.7	11.8
Cross	1	36	70	3.0	12.2	0.0
All breeds	56	40	72	2.14	12.3	14.3
	Range	16–144*	41–124	1–6	4.3–32.1	.....

* Only one case was contracted after 48 hours of age.

duration of individual cases. The size and distribution of the doses is shown further in table 6. In 89 per cent of the cases treatment was necessary for a maximum period of only 12 hours, during which not more than three doses were given. In the early part of this investigation, it was observed that when the initial dose was large and subsequent doses were smaller the rate of recovery seemed to be more rapid than when the same total quantity was given in equal doses; hence the adoption of a schedule in which the dosage size was reduced as treatment progressed. The over-all average amount of sulfaguanidine given per 100 pounds body weight in the first three doses was 7.0 grams, 5.0 grams and 4.0 grams, and the average time intervals between doses was five hours between the first two and six hours between the last two.

Presumably the rapid course of the scours necessitates the establishment of a high concentration of sulfaguanidine in the gastro-intestinal tract at an early stage to prevent irreparable damage to the tissues. Thus a large initial dose is deemed advisable. Furthermore, the scouring calf sometimes con-

TABLE 6

Quantity and distribution of therapeutic doses of sulfaguanidine given for scours in new-born calves

Maximum No. of doses given	Dosage/cwt. of calf		Cases treated	Ave. time between doses
	Average	Range		
	grams	*grams*	*per cent*	*hours*
1	6.8	3.3– 9.8	39	.....
2	6.3	2.8–10.2*	25	5
3	5.3	2.0–10.0	25	6
4	5.3	1.8– 9.8	5	8–12†
5	4.5	2.5–10.0	4	6
6	5.3	3.4– 8.5	2	6

* One severe case, not included, received a 19-gram initial dose from which the response was favorable.

† Discontinued P.M. and resumed following A.M. in most cases.

tinues to weaken after the first dosing, and the difficulty of swallowing a subsequent dose frequently increases. The weaker the calf becomes the more relaxed the esophageal groove is likely to be, permitting the passage of either a portion or all of the sulfaguanidine into the rumenoreticular cavity, where the chemical is ineffective.

Even though prophylactics did not prevent scours in all cases, they always reduced the severity of the malady. The relationship between the prophylactic measures and the responses from therapeutic dosage with sulfaguanidine is indicated in table 7. Although serum *per se* was ineffective as a preventive, it was a beneficial adjuvant in sulfaguanidine therapy. The high efficiency of sulfonamide prophylaxis reduced the incidence of scours to the extent that only a small number of cases needed treatment.

TABLE 7

The relation of prophylactic treatment to effectiveness of sulfaguanidine therapy in scours of new-born calves

Prophylaxis	Therapeutically treated with sulfaguanidine	
	No. of calves	Mortality rate
		per cent
None	35	20.0
Serum	18	5.6
Sulfonamides	3	0.0

DISCUSSION

The recurring cycle of scours among new-born calves consists of eruptive outbreaks of high incidence for a short period followed by sporadic cases during a longer period. This suggests a marked variation in the susceptibility of the calves and/or in the virulence of the causal agents. The specific factors involved in this variability have not been disclosed, but in general practice scrupulous sanitation of the surroundings and proper nutrition of the calf are indispensable measures in breaking the cycle. These basic procedures used in conjunction with sulfaguanidine treatments have proved highly effective in reducing the incidence and the severity of the malady.

The efficacy of sulfaguanidine prophylaxis and therapy depends on numerous interrelated factors among which the more important ones probably are prenatal nutrition, congenital abnormalities, portal of entry of causative elements, time of infection (ante- or post-natal), virulence and quantity of infective agents resident in the herd environment, age when calf first nurses, quality and amount of colostrum consumed and regularity of consumption. Of these, the early post-natal nutrition merits special emphasis.

Since Smith and Little (24) focused attention on the significance of colostrum in combatting scours of new-born calves, other investigators (20,

22, 27) have associated the vitamin A activity of this secretion with its protective characteristics. Therefore, Stewart and McCallum (26) reasoned that the occurrence of scours and allied infections might be considerably lessened in herds if the vitamin A activity of the colostrum of all the cows could be maintained at a high level so that each calf would receive a sufficiency of this vitamin at birth. It was further assumed that increasing the vitamin A activity of the gestation diet, by feeding either carrots or cod-liver oil, would increase the level of this vitamin in the colostrum. Results from investigations based on these premises were negative. These findings in conjunction with general observations made in the study herein reported indicate that in a well-fed herd, the incidence of scours among the new-born calves is not related to the gestation diets of the dams.

It has been noted further that whenever the udders of individual dams fail to develop and distend normally, the immediate post-partum mammary secretions usually do not possess the properties characteristic of colostrum, and the new-born offspring have a low degree of resistance to scours. In these cases, it is advisable to increase the prophylactic doses of sulfaguanidine and to feed colostrum from another cow. These practical observations indicate the need for additional fundamental information on the relation of the potency of the immunizing agents of colostrum to its chemical composition and physical properties.

Frequent consumption of small amounts of colostrum tends to prevent abomasal over-distension, which predisposes the calf to scours (25, 32). Either delay in the initial nursing or increasing the intervals between periods of consumption stimulates overfeeding and distension if the quantity of food is unlimited. If the calf is permitted to nurse at will during the first three to five days, which in many herds is the time it normally remains with its dam, scours resulting from overconsumption of colostral milk is uncommon.

In the treatment of diarrhea of new-born calves failures of sulfaguanidine therapy may be ascribed to several factors among which delay in treatment, early age at which scours is contracted, presence of excessive amounts of colostrum in the digestive tract and chemo-toxicity are probably the most frequently involved. The absence of pronounced premonitory symptoms and the rapid course of the disease occasionally result in the malady reaching an advanced stage before treatment is started. Cases of this type are encountered most often in the morning, having gone unobserved through the night. This hazard further emphasizes the importance of preventive measures in herds where the disease is entrenched.

The earlier the diarrhea develops after birth the more difficult it is to overcome. Fortunately, the manifestation of scours in calves less than 24 hours of age is exceptional. These early cases may be ascribed either to a possible *in utero* infection or to an inhibition of the normal protective

activity within the calf (25). The latter may be brought about by inherent morphological and functional defects of the digestive tract and/or by delayed feeding of colostrum. Furthermore, in treating these cases of diarrhea the sulfaguanidine may be absorbed so rapidly that it becomes difficult to establish a bacteriostatic or bactericidal concentration in the alimentary canal. This possibility merits further exploration.

Another aspect of the problem of treating the calf less than 24 hours of age and the calf that is in an advanced stage of diarrhea is that of toxicity from the sulfaguanidine (29). The increased permeability of the intestines in these cases may permit the passage of the chemical in sufficient amounts to develop toxic concentrations in the system. Dehydration accompanying diarrhea possibly further augments the toxic reactions, thus increasing the complications and fatalities (1). This potential danger should be considered when sulfaguanidine is used in treating diarrhea of calves.

The therapeutic efficiency of sulfaguanidine is exceptionally low in scouring calves that are bloated. This symptom usually indicates digestive failures as evidenced by the retention of large amounts of curd in the abomasum. In these cases portions of the doses are diverted into the rumenoreticular cavity, thus lowering the efficiency of the treatment. In addition it is possible that the coagulated material in the gastric secretions obstructs the passage of the medicine into the intestines and/or otherwise reduces its effectiveness. The *a priori* relationships of the factors involved in scours, bloat and indigestion are obscure, but the deleterious effects of loading the digestive tract of the scouring calf with milk are obvious. Therefore, during the acute stages of the diarrhea of new-born calves, it is essential that all food be withheld.

Although the therapeutic efficiency of sulfaguanidine as indicated in the experimental results is relatively high, its prophylactic use should be given precedence in herds where scours of the new-born calves prevails. Whenever therapeutic measures are necessary, it is well to give the sulfaguanidine as a drench. Giving liberal amounts of warm water between doses may retard the rate of dehydration and lessen the concentration of the chemical in the urine. Though no experimental observations were made, it is probable that parenteral administrations of isotonic solutions of either glucose or sodium chloride may be valuable supportive treatments to guard against excessive dehydration. During the convalescent period, meticulous care sometimes is necessary to avert complications, particularly pneumonia. Anorexia and general weakness occasionally necessitate force-feeding, in which case supplementing the colostral milk with cod liver oil seems to accelerate recovery.

SUMMARY

1. An acute infectious and contagious diarrhea ("white scours") of new-born dairy calves was investigated clinically.

2. Scrupulous sanitation of the surroundings and adequate nutrition of the calf during the immediate post-natal period are regarded as fundamental in the control of scours of new-born calves but such measures alone are not adequate to control the disease under general herd conditions.

3. No recognizable reduction in the incidence of scours resulted from either giving cod liver oil as a dietary supplement or injecting a commercial anti-scour serum as a prophylactic measure.

4. Sulfaguanidine given in proper doses was effective prophylactically and therapeutically. A rule-of-the-thumb procedure could not be followed in all dosing.

5. As a prophylactic agent, it is recommended that sulfaguanidine in doses of approximately two grams be given to the calf at the following intervals: first dose, shortly after first colostrum consumption, which should not be later than two hours after birth; second dose, six to eight hours later; subsequent doses, morning and night through the second or third day. Doses may be reduced to one gram after the first 36 hours.

6. The following amounts of sulfaguanidine, per 100 pounds body weight of calf, given at four to six hour intervals are recommended as a guide for treatment: first dose, 7 grams; second dose, 5 grams; third and subsequent doses, 4 grams. These doses should be varied according to the condition and response of the calf. During the first 24 hours after the first clinical symptoms of scours are manifested, all feed should be withheld from the calf and liberal amounts of warm water should be given. Discontinue the sulfaguanidine therapy as soon as scours subsides.

7. In view of the dangers from complications associated with diarrhea of the new-born calf, prophylactic measures should be given precedence over therapeutic control except in herds where only sporadic cases occur.

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ABSTRACTS OF LITERATURE

BOOK REVIEWS

360. The Microbiology of Foods. FRED WILBUR TANNER, Univ. of Ill., Urbana, Ill. Second Ed. Published by Garrard Press, Champaign, Ill. 1196 pages. $12.50.

The second edition of this book is completely revised and considerably enlarged. In addition to microbiology of all types of foods, the author has included general discussions on food preservation and characteristics and classification of bacteria, yeasts and molds. Other chapters are devoted to the bacteriology of water and sewage, intestinal microbiology, microbiological methods of assaying foods for vitamins and culture media.

Eight chapters covering 345 pages deal entirely with microbiology of milk and milk products. The subjects included are: Microbiology of milk, bacteriological milk analysis, pasteurization of milk, microbiology of cream and butter, microbiology of cheese, microbiology of frozen desserts, ice cream and similar products, microbiology of concentrated milks and fermented milks. Sanitation and sanitary methods in relation to microbiology and quality of milk and milk products are not very thoroughly discussed with the exception of glass milk bottles and paper milk containers. The discussions on the last two named subjects admirably sum up available information on them. The chapter on microbiology of cream and butter includes most of the newer developments in this field such as the mold mycelia work. The discussion on butter cultures is comparatively brief. The same might be said of the chapters dealing with microbiology of cheese and dried milk.

This book is intended as a reference source. Because of its detail and numerous references to original reports and because it often does not summarize or reconcile conflicting reports on certain subjects, its use as a text may be limited somewhat. Nevertheless, the author attempts to bring the reader up to date on all phases covered. Many useful methods are outlined in detail. A number of methods that are presented are perhaps obsolete and might well have been omitted. In general the books should be valuable as a reference book for instruction purposes and for any laboratories interested in any phase of microbiology of foods. P.R.E.

361. Advances in Enzymology. Volume 4. F. F. NORD AND C. H. WERKMAN, Editors. Eight chapters, 330 pages, including volume index and cumulative index of volumes 1, 2, and 3. Interscience Publishers, Inc., 215 Fourth Ave., New York. $5.50.

This is the fourth of a series of volumes containing reviews by authorities in the field of enzymology. Previous volumes have been reviewed in the JOURNAL OF DAIRY SCIENCE. The review articles are definitely tools for the

research laboratory. At least several of the review articles in this current volume are of immediate interest to dairy research workers. These include Gramicidin, Tyrocidin and Tyrothricin by Hotchkiss; The Influence of Hormones on Enzymatic Reactions by Jensen and Tennebaum; and the Absorption Spectra of Vitamins, Hormones and Enzymes by Brode. The review on the chemotherapic agents by Hotchkiss is quite inclusive and instructive in the light of efforts to utilize these agents in the control of mastitis. This chapter includes a discussion on chemical nature and origin, the biological properties, and the mode of action of the chemotherapic agents. The chapter on absorption spectra includes considerable graphic data. Other reviews in the volume include Chemical Formulation of Gene Structure and Action; The Specificity, Classification and Mechanism of Action of Glycosidases; The Transamination Reaction; Tyrosinase; Energy Transformations and the Cancer Problem. K.G.W.

BACTERIOLOGY

362. Classification of the Organisms Important in Dairy Products. IV. *Bacterium linens.* J. OSCAR ALBERT, H. F. LONG, AND B. W. HAMMER, Iowa State Col., Ames, Iowa. Iowa Agr. Expt. Sta. Res. Bul. 328, pp. 234–259. June, 1944.

The authors have developed a technic for the isolation of *Bact. linens* from various sources. A special cheese agar was used which included potassium citrate, sodium oxalate and five per cent sodium chloride; and the smeared plates were incubated in oxygen. With this procedure *Bact. linens* developed readily, and the color production was more intense than when tryptone glucose extract agar was used and the plates incubated in air.

This organism was found to be widely distributed in certain dairy products and materials about stables but was rarely found in soil.

An alkaline reaction in litmus milk and then conspicuous proteolysis were produced by *Bact. linens.* It increased the soluble nitrogen in milk on extended incubation, but the extent of proteolysis varied considerably with different strains of the bacterium. The authors also found that the amino nitrogen, the fraction soluble in trichloracetic acid and the soluble and insoluble fractions in ethyl alcohol or phosphotungstic acid were significantly increased.

Bact. linens was not lipolytic. It produced a putrid condition in salted and unsalted butter at 21° C. The organism produced volatile acids from various alcohols when grown in a medium consisting of 0.3 per cent desiccated yeast extract in water. It grew at a pH of approximately 6.0 but not at a pH of approximately 5.0 in two per cent peptone solution. It also grew at a pH of approximately 9.8. The authors show that *Bact. linens* decreased rapidly in number in litmus milk in the presence of *S. lactis.* It survived

at least 4 months in litmus milk at room temperature, and when dried on filter paper it survived for at least 3 months.

Bact. linens tolerated 15 per cent sodium chloride in broth or skimmilk, and there was some growth in considerably higher concentrations. The authors also found that it was easily destroyed by heat and actively produced catalase.

A detailed description of *Bact. linens* is given in the bulletin. B.E.H.

BREEDING

363. A Comparison of Inbreeding and Outbreeding in Holstein-Friesian Cattle. J. W. Bartlett and S. Margolin. N. J. Agr. Expt. Sta. Bul. 712. 28 pages. June, 1944.

The Holstein breeding project of the New Jersey Agricultural Experiment Station was analyzed by cow families with respect to growth, production and health. The records were examined qualitatively by means of the graphic system of Bartlett *et al.* and by the use of statistical treatment. The influence of inbreeding as compared with outbreeding was considered with respect to growth, production and health of the animals. The general conclusions derived from these studies follow:

Specific cow families and sires have the facility consistently to transmit genetic factors for superior size (height at withers measure), type, percentage butterfat, milk production, and total fat. These are cited in the observations.

At present, dairy cattle can be inbred up to a coefficient of 0.30 without reducing frame size (as measured by height and heart girth). As the undesirable recessive factors are eliminated by inbreeding and selection, it should be possible eventually to increase the coefficient of inbreeding beyond 0.20 without detrimental effects, since these latter results are due to the genetic structure rather than the actual inbreeding process. All inbred animals were superior in type to outbred animals.

The total fat production was higher for the outbred than for the inbred progeny of the same sire. Outbreeding increased total fat, whereas inbreeding merely maintained it.

When the same sires were used, inbreeding raised the percentage butterfat test twice as much as outbreeding without significantly modifying milk production. In some families there was a tendency for milk production to decline as percentage fat was increased, whereas in others, milk production was maintained as the butterfat test was increased.

Outbreeding highly inbred bulls of superior qualities produced much more rapid breeding progress than inbreeding these sires. Furthermore, the rapid improvement obtained by outbreeding superior inbred sires was markedly greater than that obtained by outbreeding superior outbred sires.

The primary contribution of the inbreeding work, thus far, lies in the development of superior inbred sires. These sires have demonstrated a marked prepotency for desirable growth, type, butterfat test, and milk production; this is probably due to the homozygosity obtained by inbreeding. The marked improvement in the production record of the herd during the last decade is probably an outcome of the inbreeding program which made the development of these prepotent superior sires possible.

A short appendix to the bulletin outlines a plan for analysis of a breeding program in which consideration is given to growth, production and health. J.G.A.

BUTTER

364. Use of Neutralizer. S. T. COULTER, Univ. of Minn., St. Paul, Minn. Amer. Butter Rev., *6*, No. 8: 256. Aug., 1944.

With relatively low acid cream it is best to add neutralizer to the cold cream and agitate 10 to 15 minutes before starting to heat. If neutralizer is to be added after pasteurization, it is best, with high acid cream, to reduce the acidity to 0.25 per cent before pasteurization. Cream must be neutralized to 0.15 or slightly less per cent titratable acidity to bring the pH of the butter serum within the desirable pH range of 6.8 to 7.2. It is most important that cream be neutralized to the correct acidity, and care must be exercised accordingly in weight determinations, test accuracy, and solution strength. If the excellent neutralizer, caustic soda, is used, each pound may be added to 10 pounds of water and the mixture cooled before addition to the cream, if neutralizer flavor is to be avoided. P.S.L.

CHEESE

365. Comparison of Methods for Determining Fat Content of Cheese With Particular Reference to Blue Cheese. F. J. BABEL AND F. E. NELSON, Iowa Agr. Expt. Sta., Ames, Iowa. Natl. Butter and Cheese Jour., *35*, No. 9: 18. Sept., 1944.

Fat in ripening cheese is partially hydrolyzed. The Mojonnier method extracts fat from alkaline solution, and the ammonium soaps encountered when free acids are present are not extracted in the organic solvents used because they are more soluble in water. This method, the A.O.A.C. Official Method and the Babcock method were compared in analyzing young and aged Blue and Cheddar cheese. Results on 10 samples of Blue cheese show that the Mojonnier method gives distinctly and consistently lower results than the Official method, especially with aged cheese, while the Babcock method agrees better with the Official method but is usually slightly lower. Six samples of Cheddar show similar trends. There is a direct relation between

the extent of fat hydrolysis and the variations encountered between the Mojonnier and Official methods. W.V.P.

366. The Survival of *E. typhosa* in Cheddar Cheese Manufactured from Infected Raw Milk. A. G. CAMPBELL AND J. GIBBARD, Dept. of Pensions and Natl. Health, Ottawa, Canada. Canad. Pub. Health Jour., *35*, No. 4: 158. 1944.

A series of experiments are described in which small vats of raw milk were seeded with various cultures of *E. typhosa* at calculated rates of 1,000 to 600,000 organisms per ml. of milk. This was manufactured into Cheddar cheese, samples of which were ripened at 40–42° F. and 58–60° F. Survival was determined by plating dilutions directly on MacConkey's as well as by transferring dilutions and/or macerated cheese to tetrathionate broth as an enrichment medium.

There was a significant difference in the viability of *E. typhosa* in cheese stored at 40–42° F. compared with that at 58–60° F. Seven out of the ten cheese stored at the lower temperature retained *E. typhosa* for over 300 days whereas it appeared that at 58–60° F. most of the *E. typhosa* were dead after three months. There appeared to be no difference in the longevity of the infecting organisms as a result of the size of inoculum. However, one strain (phage type M) appeared to be more resistant than the other two studied. Titratable acidity determinations made at intervals during ripening indicated that the higher temperature hastened acidity increases. These higher acidities could not be correlated with the death of the infecting organisms however. O.R.I.

CHEMISTRY

367. General Characteristics of the Partial Hydrolysis Products from the Action of Proteolytic Enzymes on Casein. THEODORE WINNICK, Dept. of Chem., Univ. of Idaho, Moscow, Idaho. Jour. Biol. Chem., *152*, No. 2. Feb., 1944.

A study was made of the partial hydrolysis products from the action on casein of the enzymes pepsin, trypsin chymotrypsin, ficin, papain, and carboxypeptidase.

Following digestions with proteases, the average non-protein molecules contained from 5 to 7 amino acid residues, with 1.5 to 4.5 per cent of the total nitrogen in the form of free amino acids. After the removal of inorganic electrolytes in electrodialysis, some additional characteristics of the digestion products were determined, including the nitrogen content, specific rotation, and average molecular weight.

The further action of carboxypeptidase on protease digests of casein was interpreted as the splitting of free acids from the ends of polypeptide chains.

The initial products from short periods of protein digestion were compared with those from prolonged protease action. The specific rotations and ratios of amino to total nitrogen of the products did not differ significantly in these two cases, in agreement with a recent speculation on the mechanism of proteolysis. A.O.C.

368. Component Fatty Acids of Early and Mature Human Milk Fat. A. Richard Baldwin and Herbert E. Longenecker, Dept. of Chem., Univ. of Pittsburgh, Pittsburgh. Jour. Biol. Chem., *154*, No. 1: 255–265. June, 1944.

Three composite samples of human milk were studied. The first two were taken from 75 individuals during the first 3 days post partum, and the third was taken from two individuals during the 22nd to 43rd day of lactation. All samples were dried by the cryotherm process; and after extraction the lipids (62.1 gms. in all) were analyzed for phospholipids, volatile fatty acids, non-volatile fatty acids, and other fat constants. Fractional distillations of the methyl esters were made.

The percentage of fat increased in the mature milk and the relatively high phospholipid content of the colostrum was markedly reduced as lactation advanced. In comparing these analyses with cow's milk fat, the most interesting observation is the relatively small amounts of low molecular weight fatty acids in the human milk fat. "Although this fact has been known previously, there has been a tendency to emphasize the occurrence of these acids in cow's milk fat as having some special significance in infant feeding. These acids, however, are not present in human milk fat in sufficient quantity to make the infant's need for them credible solely on the basis of their occurrence." The human milk fat showed larger amounts of the eighteen carbon atom fatty acids than normal cow's milk fat; and yet "the octadecadienoic acid in human milk fat may not be identical with linoleic acid of ordinary seed fat, although the latter may be present in traces." A.O.C.

369. Fluorescence Development in Various Food Products. Jesse A. Pearce, Natl. Res. Labs., Ottawa, Canada. Canad. Jour. Res, *22*, Sect. F, No. 4: 87. 1944.

Fluorescing substances developed in the following materials during storage: high protein foods, represented by dried whole milk powder, dehydrated pork, and soya flour; high carbohydrate foods, represented by dried banana flakes and dried parsnips; and a mixed foodstuff, represented by ration biscuits.

The only change occurring in stored shortenings was a decrease of fluorescing substances in hydrogenated linseed oils. Serum extracted from

rancid butter had a higher fluorescence value than serum from fresh butter. In substances containing a high proportion of fat, fluorescence values bore little relation to deterioration as assessed by peroxide oxygen determinations.

Fluorescence tests were unsatisfactory for dried milk powders and soya flour. However, they may prove useful as a measure of the quality of dehydrated pork, dried banana, dried parsnips, ration biscuits and butter. (Author's abstract.) O.R.I.

CONCENTRATED AND DRY MILK; BY-PRODUCTS

370. Future of Dried Whole Milk. P. H. Tracy, Univ. of Ill., Urbana, Ill. Amer. Milk Rev., *6*, No. 8: 234. Aug., 1944.

Dried whole milk may become a competitor for fresh whole milk, especially in bread making, the ice cream industry, and in the making of cultured buttermilk and chocolate milk. To become so, it must be a better product than formerly, be more convenient to use, and be cheaper. One of its chief faults is its tendency to develop a tallowy flavor. This tendency can be reduced by fore-warming to 170° F. for 20 minutes, or 250° for one second; high concentration; low copper content; large particle size; packaging hot; low oxygen in the package; regassing with nitrogen after 24 hours; and storage at low temperatures. The use of dried whole milk in the home will require a great amount of persistent advertising. P.S.L.

371. The Manufacture of Crude and Technical Lactose from Cheese Whey. B. H. Webb and G. A. Ramsdell, Div. of Dairy Res., U.S.D.A., Washington, D. C. Natl. Butter and Cheese Jour., *35*, No. 7: 18, July, 1944; and *35*, No. 8: 18, Aug., 1944.

Crude lactose contains at least 2% more protein-plus-ash than U.S.P. specifications permit; technical lactose is somewhat better; both must be refined to make U.S.P. grade. Crude and technical lactose can be used for human food products. Profitable manufacture requires at least 75,000 lbs. of sweet whey per day. Equipment must include vacuum pan, filter press and sugar centrifuge.

Lactose is separated from whey by clarification, concentration, crystallization and centrifuging. Proper clarification is essential to obtain a low protein and ash content in the sugar; this can be accomplished with calcium chloride, lime and hydrochloric acid, but about one-third of the original nitrogen remains in the treated whey. Concentration causes the precipitation of the insoluble salts and nitrogenous material; this requires reclarification by filtration during concentration—whey from rennet curd is particularly troublesome in this respect. The resulting lactose often contains foam-producing impurities which can be removed by recrystallizing. When 10,000 parts of clarified whey is treated with one part of the enzyme trypsin

at 130° F. and at pH 6.2 to 6.4 for one to two hours, a non-foaming sugar results after one crystallization.

Six processes for making lactose from cheese whey are briefly described. (1) The simplified crude process concentrates whey to 55 to 60% solids, crystallizes the lactose and centrifuges away the mother liquor. This product is high in whey solids. (2) The soluble albumin process concentrates neutralized whey to 62% solids, holds the concentrate at 32° to 38° for 18 hours and then centrifuges out the lactose. (3) The sweetened condensed whey process concentrates whey sweetened with about 6% sucrose to 70% total solids, holds the concentrate overnight, centrifuges out 1 to 2 lbs. lactose per cwt. whey, leaving the mother liquor for use in sweetened foods. (4) The simplified technical process clarifies the whey by heat and acid, siphons off and concentrates the clear whey to 34° Baumé at 120° F., crystallizes the lactose slowly and removes it by centrifuging. (5) The technical process clarifies whey as in process 4, siphons or filters off the whey, concentrates it to 20° Baumé (30% lactose) decolorizes with carbon, heats the sirup to boiling, cools overnight, neutralizes to pH 6.3, boils again, filters, concentrates to 38 to 40° Baumé, centrifuges out lactose, washes and dries crystals. (6) The trypsin process clarifies whey as in process 4, neutralizes to pH 6.3, boils, filters, adds one pound of trypsin to 10,000 lbs. whey, holds one hour at 132°–138° F., concentrates to 20° Baumé and then finishes as in process 5. This process can be used with cottage cheese or casein whey.

W.V.P.

FEEDS AND FEEDING

372. Determination of Carotene in Dehydrated Alfalfa. A Simplified Method. RALPH E. SILKER, W. G. SCHRENK, AND H. H. KING. Kans. Agr. Expt. Sta., Dehydration Lab., Manhattan, Kans. Jour. Indus. and Engin. Chem., Analyt. Ed., *16,* No. 8: 513. Aug., 1944.

A simplified method, which avoids refluxing and phasic separations, was developed for the determination of carotene in dehydrated alfalfa. Finely ground alfalfa was allowed to stand for 16 to 18 hours in a mixture of acetone and Skellysolve B, the extract was concentrated on a steam bath to remove the acetone, the pigments were adsorbed by drawing the mixture through a magnesia column, and the carotene then eluted with a 4% solution of acetone in Skellysolve B. The solution of carotene was made up to volume and analyzed with a Beckman spectrophotometer. B.H.W.

373. Comparison of Molasses-Oat Silage and Phosphoric Acid-Oat Silage as Feeds for the Milking Cow. W. A. KING. N. J. Agr. Expt. Sta. Bul. 708. 22 pages. March, 1944.

Results are reported of feeding, digestion, and N, Ca, and P balance trials

on these two types of silage with 21 cows over a period of four months during the winter of 1941–42.

Molasses-oat silage proved to be superior to phosphoric acid-oat silage in a number of ways: in phosphorus retention, in palatability, in economy of milk production, and in absence of physiological disturbances.

The oat silages were not so palatable as good corn silage; but they proved to be as good, if not better in the case of the molasses-oat silage, in economy of milk production.

There were no great differences between the digestibility of the two oat silages. The coefficient of digestibility of the crude protein was definitely higher in the phosphoric acid silage. At the same time an increased nitrogen excretion in the urine of these cows was evident, indicating that this extra digested protein was not of great value for anabolic purposes.

The coefficients of digestibility of the two oat silages when fed alone were considerably higher than when the silages were supplemented with hay and grain.

The phosphorus balance of the cows fed the phosphoric acid-oat silage with limestone showed a negative balance of 18.9 gm. daily, whereas those fed the molasses-oat silage rations and the phosphoric acid silage supplemented with hay and grain were in a positive balance. Only the group fed the molasses-oat silage alone showed a negative calcium balance. The other groups of cows received calcium supplements. J.G.A.

374. Effect of Feeding Silages on Certain Properties of Milk: I. Effect on the Yellow Color and Flavor of Winter Milk. II. Influence on the Vitamin A Content and Distribution of Carotenoid Pigments in Milk Fat. III. Effect of Various Storage Conditions on the Stability of Carotenoid Pigments in Butter. O. F. GARRETT AND D. K. BOSSHARDT. N. J. Agr. Expt. Sta. Bul. 710. 30 pages. March, 1944.

This study extended over three feeding seasons—1940–41 through 1942–43. The three kinds of silage studied were made respectively from alfalfa, green oats, and soybeans. All were compared with corn silage as a control. Preservatives used were molasses and phosphoric acid for the alfalfa and oat silages, and molasses and corn meal for the soybean silage. Nine Holstein cows were used in each trial, three in the control group which received corn silage and three each in the other two groups.

Conclusions on the three aspects of the work were:

I. Alfalfa silage, whether preserved with molasses or with phosphoric acid, is capable of producing milk with higher yellow color, better flavor, and greater resistance to the development of oxidized flavor than that produced with corn silage, whereas green oat silage and soy-

bean silage are about equivalent to corn silage with respect to these factors.

II. Eight bands, or zones, of carotenoid pigments were chromatographically isolated from corn silage, molasses-soybean silage, and cornmeal-soybean silage, and from the milk fats produced on these roughages. Only seven bands were found in pasture grass and the milk fat produced therefrom.

The observation of others that the cow is capable of selecting beta-carotene from among the various plant carotenoids and concentrating it in the milk fat is verified by the results of these studies.

Milk produced on soybean silages contained approximately the same amount of total carotenoid pigment, carotene, and vitamin A as milk produced on corn silage.

The concentration of total vitamin A in Holstein milk fat was approximately the same as that of Guernsey milk fat when the feed was the same for the two groups. Guernsey milk, however, contained more total vitamin A per quart than Holstein milk under the same conditions of feeding. The Holsteins used in this experiment produced about twice as much true vitamin A and about 25 per cent more total vitamin A but only about one-half as much carotene per day as the Guernseys.

There was some tendency for true vitamin A to vary directly with the carotene in the Holstein milk, but no such relationship was found in the Guernsey milk.

A high correlation was found between lactochrometer readings and the concentration of total pigment in milk, which justifies the use of the lactochrometer as an instrument for measuring the yellow color of milk.

III. The carotenoid pigments of milk fat are not entirely stable during storage, even when no known contamination with copper occurs.
Alpha-carotene is the least stable and beta-carotene the most stable of the definitely identified pigments.

The presence of copper accelerates the destruction of beta-carotene but has little influence on alpha-carotene and xanthophyll.
There is a slight tendency for manganous ions to inhibit the catalytic effect of cupric ions.

Hydroquinone exhibits a definite retardation of the oxidative degradation of beta-carotene both in the presence and in the absence of added cupric ions.

There appears to be a progressive formation and destruction of the pigments in bands IIIa, IIIb, and IV. Undoubtedly these pigments are degradation products of alpha- and beta-carotene, since they fall in the chromatogram above the carotenes and below the xanthophyll group, thus indicating a larger amount of oxygen in the molecule. Their stronger affinity for the adsorbent is evidence of this fact.

J.G.A.

375. Riboflavin Content of Milk Products for Feeding Purposes. E. V. Evans, D. M. Young, and H. D. Branion, Ontario Res. Found., Toronto and Ontario Agr. Col., Guelph, Canada. Sci. Agr., *24*, No. 11: 510. 1944.

Microbiological assays were conducted on 58 samples of buttermilk powder, 35 samples of skimmilk powder and 9 samples of whey powder. All were of the type used in poultry and hog concentrates. Wide variations in the riboflavin content of similar products were found. The values for buttermilk powder ranged from 22 to 47 micrograms per gram, while the range was 17–23 in the case of skimmilk powder and 14–24 for the whey powder. O.R.I.

FOOD VALUE OF DAIRY PRODUCTS

376. For the Greatest Common Good. Hugo Sommer, Univ. of Wis., Madison, Wis. Natl. Butter and Cheese Jour., *35*, No. 8: 17, Aug., 1944; and *35*, No. 9: 56, Sept., 1944.

Our opposition to repeal of the federal tax on yellow margarine is not based on the question of nutritive equivalency. Such equivalency we do not concede because there are still unanswered questions in this field. We oppose repeal for these reasons: (1) Colored margarine would be sold as butter, the incentive being that oleo fats cost only one-fifth to one-fourth as much as milk fat. (2) Prices of all dairy products would be depressed. (3) Changes in farm practices would decrease soil fertility; even the advocates of oleo recognize that increasing field crops at the expense of livestock involves soil mining and erosion. (4) Decreased use of milk solids would be a loss in terms of human health and this despite the increased use of oleo by low-income groups which would follow repeal of the tax and coloring of oleo. The depression in prices of dairy products would reduce production of non-fat dry milk solids, a by-product which is considered essential as a bread ingredient to provide essential minerals and vitamins. Bread is a staple of the low-income-group diet. We cannot at the same time expand the use of oleo and still expect to expand the enrichment of bread with milk solids. (5) A dangerous precedent would be set in the field of imitation of food products. Actually synthetic edible fats made from petroleum

paraffin are now being made in Europe and might be introduced here with embarrassing results. Filled milk, filled cheese and filled ice cream become definite possibilities with repeal of the tax. (6) The common good of consumers, dairy farmers and producers of oil crops would all be adversely affected by repeal of the tax on colored oleo. The consumer would get less protection against fraud. Even if oleomargarine largely displaced butter, the gain in oil values could not possibly approach the loss to the dairy industry. Loss of a substantial part of the butter market would cause decided losses to the whole industry and millions of dairy farmers since the price structure of dairy products is based on the butter market. W.V.P.

HERD MANAGEMENT

377. Better Crop and Herd Management on New Jersey Dairy Farms. G. E. TAYLOR, H. R. COX, G. H. AHLGREN, AND F. E. BEAR. N. J. Agr. Ext. Serv. Bul. 239. 12 pages. March, 1944.

This bulletin is based on the premise that "New Jersey dairymen can best safeguard their position in the feed situation by growing more and better quality roughage." It contains numerous specific recommendations on soil management, the growing of hay, pasture, and silage crops, and on dairy cattle feeding and management. J.G.A.

ICE CREAM

378. The Relative Sweetnesses of Certain Sugars, Mixture of Sugars, and Glycerol. A. T. CAMERON, Dept. of Biochem., Univ. of Manitoba, Winnepeg, Canada. Canad. Jour. Res., *22*, Sect. E, No. 3: 45. 1944.

The relative sweetnesses of the sugars glucose and lactose and of the alcohol glycerol, as compared with sucrose, vary with concentration.

The relative sweetness of glucose or lactose or glycerol, compared with either of the other two, does not change with concentration, within the limits of the experimental method used.

The following have been found to be equally sweet:

(i) 2.0% sucrose and 3.8% glucose; 10.0% sucrose and 14.7% glucose; 20.0% sucrose and 25.0% glucose.

(ii) 2.0% sucrose and 6.5% lactose; 5.0% sucrose and 14.9% lactose; 8.0% sucrose and 21.7% lactose.

(iii) 2.25% sucrose and 4.0% glycerol; 5.5% sucrose and 8.0% glycerol; 8.9% sucrose and 12.0% glycerol.

A method is described for calculating the sweetness of a mixture of sugars of known composition in terms of that of a specific concentration of sucrose or of glucose. (From author's abstract.) O.R.I.

379. **Microbiological Aspects of Egg Powder.** C. K. JOHNS, Dept. of Agr., Ottawa, Canada. Sci. Agr., *24*, No. 8: 373. 1944.

The standards and procedure employed in the bacteriological control of Canadian dried eggs for export to Britain are described. During 1943, out of a total of 235 carlots of Grade A powder examined, over 95% gave counts of under 500,000 per gram.

As a simple plant test for the bacterial content of the melange, the Burri slant method has been found most useful. Methylene blue and resazurin tests were not so satisfactory because of end-point difficulties and the long incubation periods required. The direct microscope count was found to reveal the past history of the product more satisfactorily than did the plate count, coliform or *E. coli* test. Studies on the flora of the melange and powder revealed that the Gram negative rods which predominated in the former were generally replaced by a weak-acid-producing streptococcus in the powder.

Details are given of the methods used for bacteriological analysis. After suitable preparation and reconstitution, dilutions of the powder are plated on tryptone glucose extract agar containing 1% skim milk, the plates being incubated at 37° C. for 48 hours. For the detection of *E. coli* 2% brilliant green bile broth and eosin-methylene blue agar plates are used. O.R.I.

MILK

380. **The Pasteurization of Milk.** G. S. WILSON, Univ. of London, School of Hygiene and Tropical Medicine. Foreword by Sir Wilson Jameson. Published by Edward Arnold & Co., London. 212 pages. 18s.

In this book a review of the evidence relating to pasteurization has been made, dealing particularly with the public health and nutritional aspects of the process. The literature reviewed is extensive, with special emphasis directed to indict raw milk as a source of human disease. The experience of England and Scotland with reference to milk-borne diseases is fully described. The efficacy with which pasteurization has controlled diseases of these types in certain communities is also cited.

The book is not a manual for the milk plant operator or laboratory worker. Descriptions are given of the holder, HTST, high (flash), and Stassano methods of pasteurization although the apparatus used is not described. The laboratory control of pasteurization is critically reviewed, particular attention being paid to the importance and limitations of the phosphatase test. A very strict standard for this test is suggested, and the advice is given that it should at times be supplemented with the guinea-pig test for tubercle bacilli.

The nutritional aspects of pasteurization are discussed from the point of view of minerals, proteins, vitamins and the growth-promoting and fertility-sustaining power. The work dealing with the vitamins of the B group is somewhat incomplete, only Vitamins B_1 and B_2 being mentioned. A chapter and an appendix are devoted to refuting some of the standard arguments that are occasionally raised against pasteurization. O.R.I.

381. Meeting New York Milk Demands. LELAND SPENCER, Cornell Univ., Ithaca, N. Y. Amer. Milk Rev., *6*, No. 4: 106–108, 116–119. April, 1944.

Much milk handled by Atlantic seaboard dealers the past year has been purchased outside its normal shed and has been sold at a considerable loss. New York City escaped this condition because it maintained a potential number of inspected farms to meet peak demands. This reserve supply was greatly changed by its diversion to shortage areas during November, which, with 12.6% increase in market milk consumption, caused a shrinkage to one-half of manufactured products. New York City's demand for milk in 1944 will probably be the same as for 1943, and the same will probably be true for diversion of milk from its milk shed for November 1944. Production prospects are poorer than for 1943. Government aid can function in three ways: (1) assurance of as abundant feed as possible, (2) recognition of the necessity of labor and labor-saving equipment for the dairyman, and (3) maintenance of a price high enough to encourage dairymen to stay in business at their present size. P.S.L.

382. Factors Affecting Milk Supply in Akron, Canton, Dayton, and Portsmouth, Ohio. C. G. MCBRIDE AND R. W. SHERMAN. Ohio Agr. Expt. Sta. Bul. 652. July, 1944.

The five years 1939–1943 are included in all the markets studied; and in two markets, records for a longer period were available. The years preceding 1939 had been a period of increasing total shipments of milk to these markets. All markets were operating then under some form of base and surplus plan, and there had been a trend toward less seasonal variation in shipments.

Soon after 1939 the supply situation began to change, due to shifting of population for employment in defense plants. Of the four markets, Dayton and Akron experienced the greatest increase in demand for milk. By the fall of 1942 these markets had demand in excess of total farm shipments, and in 1943 the shortage was still greater.

Changes in market plans were made that are significant. As city sales increased, desire developed on the part of producers to do away with the base and surplus plan and thus to relieve the shipper of the necessity of taking a lower price for his "surplus" milk. One after another, beginning with Dayton and ending with Portsmouth, the markets abandoned the base

and surplus plans. Dayton introduced a quantity bonus plan to induce more shipments throughout the year. From 1939 through 1943 there has been an increase in average shipments per day, but seasonal variation of shipments has increased to a marked degree. This is a matter of real concern, because wide seasonal variation adds to the difficulties and the costs of the market milk business.

The period of withdrawals of producers in largest numbers came in 1941 and 1942. The most important reason for withdrawal from all these markets was retirement, including illness and death. Increasing demand did not turn the tide of retirement, but it appeared to induce those who remained in the market to increase their volume of shipments.

The producers whose average daily shipments were much larger than the average of the market did not hold their relative position. The reason given was the difficulty of maintaining an adequate labor force. Those with shipments below the average were more inclined to withdraw by retirement than were those in the middle brackets. The increase in shipments, therefore, came as a result of larger average shipments from farms with medium size of herd.

With dealers' sales limited by War Food Order 79, it would appear that these cities will not have great difficulty with milk supply for about 9 months of the year. Several factors work together to make fall production relatively lower, and this may create some tight supply situations in the fall months. A return to some form of base and surplus plan holds the greatest promise for solving this problem. H.P.

383. Cleaning Method Suggestions. S. T. COULTER, Univ. of Minn., St. Paul, Minn. Amer. Butter Rev., *6*, No. 4: 118–119. April, 1944.

For washing of metal equipment where a rather hard water only is available, the author has found satisfactory a mixture of 45 pounds tetrasodium pyrophosphate, 25 pounds sodium metasilicate, 25 pounds trisodium phosphate, and 5 pounds of a suitable wetting agent as Nacconol N.R. Dreft, Swerl, M.P. 189, Vel, Neosuds, etc. The very hard water for which the above was recommended contained 24 grains of hardness per gallon, 16 grains methyl orange alkalinity, and 5 grains of sulfates. The mixture is to be used at the rate of one-fourth to one-half ounce per gallon of water, or better by using one-half gallon of a stock solution per 50 gallons of water, the stock solution being prepared by dissolving 15 pounds of the dry mixture in ten gallons of water. If the wash water in the plant is softer than the example cited, less of the sequestering agent, tetrasodium pyrophosphate, may be used in the mixture. The mixture will not remove milk stone and water stone already formed, but it does not encourage their formation as does soda ash and trisodium phosphate.

For preventing milk stone formation in farm dairy utensils, the recommendation is made that a definite procedure be followed of rinsing the

utensil in lukewarm rather than cold water both before and after washing. A chlorine rinse should be given just before use only, since chlorine solution is slightly corrosive. Steaming or a hot-water rinse is proper after washing for disinfection and as an aid to rapid drying. A mixture made by the addition of a tablespoonful of one of the wetting agents previously named, per pail of water, is good when used alone for farm-utensil washing. A home-prepared paste for removal of milk stone deposits can be made by adding to Italian 4F pumice enough of a 5 per cent solution of a weak acid such as citric, tartaric, or acetic to make a paste. The deposits may be removed by scouring with this abrasive paste, followed by thorough washing and rinsing. P.S.L.

PHYSIOLOGY

384. Some Factors Affecting the Resistance of Ejaculated and Epididymal Spermatozoa of the Boar to Different Environmental Conditions. JOHN F. LASLEY AND RALPH BOGART, Dept. of Anim. Husb., Univ. of Missouri, Columbia, Mo. Amer. Jour. Physiol., *141*, No. 5: 619. July, 1944.

Secretions from the accessory glands (prostate, seminal vesicles, Cowper's and urethral glands) did not greatly influence the resistance to a cold shock or storage potentialities of boar epididymal spermatozoa. The degree of dilution, using several different diluters, had no influence upon the resistance of epididymal spermatozoa to a cold shock. Diluting suspensions of epididymal and ejaculated boar spermatozoa with egg yolk-phosphate buffer increased their resistance to a cold shock and their survival under storage conditions.

The resistance of spermatozoa to a cold shock and their ability to survive during storage varies with the place in the reproductive tract from which they are obtained. Spermatozoa from the head of the epididymis are very resistant and survive during storage for long periods, but their resistance and survival capacity decrease as the distance of their location from the testis increases until spermatozoa in the ejaculate have practically no resistance or storage potentialities. It is suggested, on the basis of the foregoing observations, that the reduction in resistance and storage potentialities of boar spermatozoa is associated with changes within the spermatozoa rather than with changes in their environment. D.E.

MISCELLANEOUS

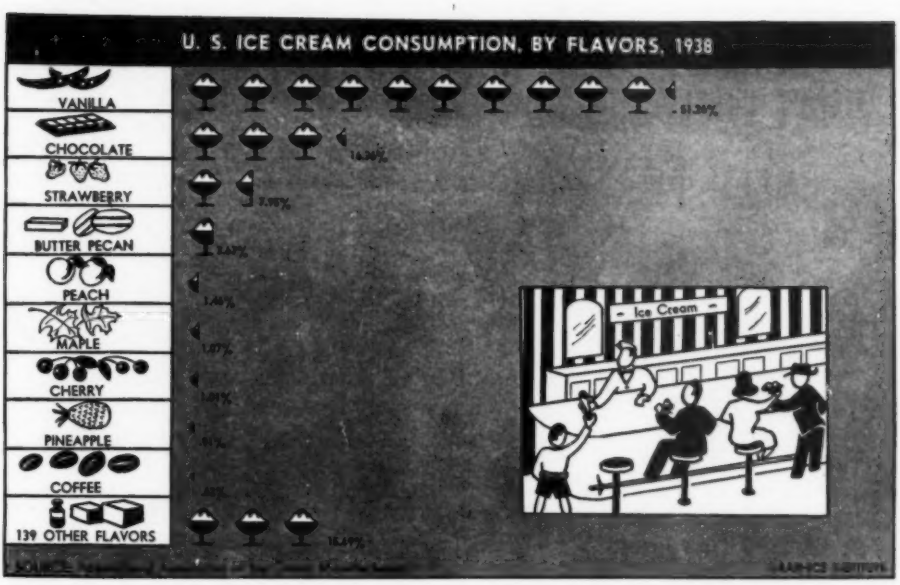
385. Tin in the Dairy Industry. JULIA BAXTER, Battelle Memorial Institute, Columbus, Ohio. Natl. Butter and Cheese Jour., *35*, No. 7: 68. July, 1944.

Although tin is a scarce, strategic metal now, new developments in

using it will favor its use after the war in the dairy industry. For example, electrolytic plating can apply economically, accurately and rapidly, definite and uniform coatings of any desired thickness to vats, cans, pipe-lines and tin plate. White bronze, a tin base material containing 35 to 50 per cent tin, and tin in combination with nickel offer new possibilities in coating copper base materials and steel. Tin with 8 per cent zinc gives a stiff foil which may be used for capping milk bottles. The life of tinned equipment can be extended by avoiding corrosive acid and alkali cleaners. W.V.P.

386. A Family and an Industry. PAUL H. MANDT, Olsen Publishing Co. Milwaukee, Wis. Natl. Butter and Cheese Jour., *35*, No. 7: 16. July, 1944.

This is an interview with Loomis Burrell, whose grandfather, Jonathan Burrell, was a pioneer in the development of dairying in New York State nearly 150 years ago. The records of Loomis Burrell and his family show the importance of cheesemaking in those days, the factory problem, the adoption of English methods, and the gradual development of better mechanical devices and marketing methods. Dates of events and inventions, names of inventors, and cuts of early machinery are interesting features of this historical sketch. W.V.P.



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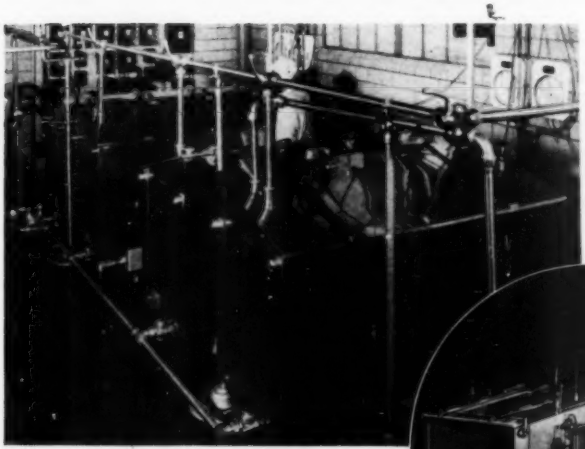

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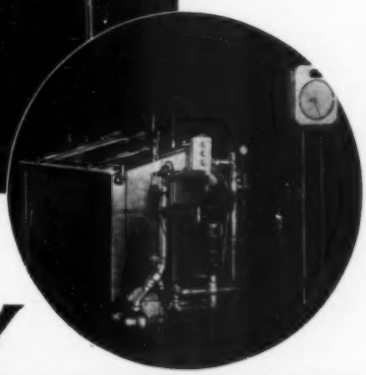

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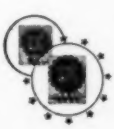

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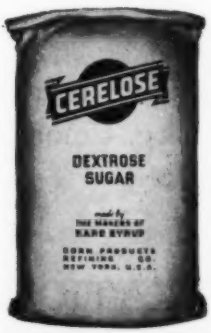

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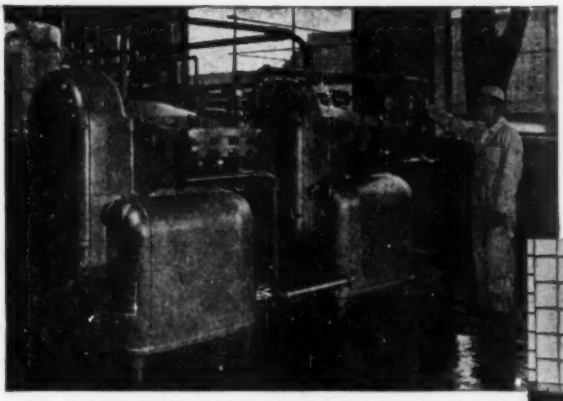

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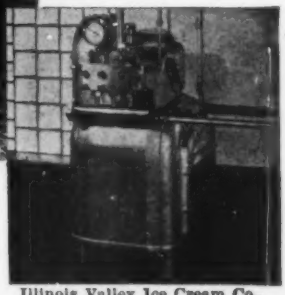

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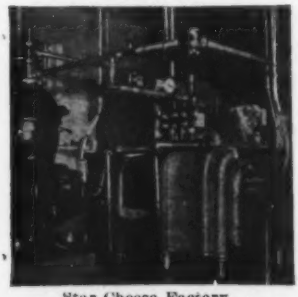

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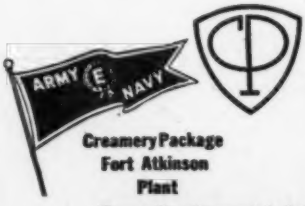

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